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Parcel G Removal Site Evaluation Work Plan

Former Hunters Point Naval Shipyard
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Building Investigation Design and Implementation

This section describes the DQOs, ROCs, RGs, ILs, and radiological investigation design and implementation for Parcel G buildings.

4.1 Data Quality Objectives

The DQOs for the building investigation are as follows:

- **Step 1-State the Problem:** Data manipulation and falsification were committed by a contractor during past building surveys. The Technical Team evaluated building data and found evidence of potential manipulation and falsification. The findings call into question the reliability of the data and there is uncertainty whether radiological contamination was present or remains in place. Therefore, the property is unable to be transferred as planned. Based on the uncertainty and the description of radiological activities in the HRA, there is a potential for residual radioactivity to be present on building interior surfaces.
- **Step 2-Identify the Objective**: The primary objective is to determine whether site conditions are compliant with the Parcel G ROD RAO (Navy, 2009).
- **Step 3-Identify Inputs to the Objective:** The inputs include alpha-beta static, alpha and beta scan, and alpha-beta swipe data on building and reference area surfaces.
- **Step 4-Define the Study Boundaries**: The study boundaries are accessible interior surfaces of Buildings 351, 351A, 366, 401, 411, and 439, and the concrete pad at former Building 408 (**Figure 4-1**). The building floor (i.e., Class 1 SUs) are depicted on **Figures 4-2** through **4-8**.
- **Step 5-Develop Decision Rules:**
  - If the investigation results demonstrate that there are no exceedances determined from a point-by-point comparison with the statistically-based RGs[8] at agreed upon statistical confidence levels, or that residual ROC concentrations are NORM or anthropogenic background, then a RACR will be developed.
  - If the investigation results demonstrate exceedances of the RGs determined from a point-by-point comparison with the statistically-based RGs[8] at agreed upon statistical confidence levels and are not shown to be NORM or anthropogenic background, then remediation will be conducted, followed by a RACR.
  - The RACR will describe the results of the investigation, explain remediation performed, compare the distribution of data from the sites with applicable reference area data, and provide a demonstration that site conditions are compliant with the Parcel G ROD RAO through the use of multiple lines of evidence including application of statistical testing with agreed upon statistical confidence levels on the background data.

[8] The RGs are statistically based because they are increments above a statistical background.

- **Step 6-Specify the Performance Criteria:** The data evaluation process for demonstrating compliance with the Parcel G ROD is presented as follows, depicted on **Figure 4-9**, and described in detail in **Section 5:**
  - Compare each net alpha and net beta result to the corresponding RG presented in **Section 4.3**. If all results are less than or equal to the RGs, then compliance with the ROD RAO is achieved.
  - Compare survey data to appropriate RBA data from HPNS as described in **Section 5**. Multiple lines of evidence will be evaluated to determine whether site conditions are consistent with NORM or anthropogenic background. The data evaluation may include, but is not limited to, population-to-population comparisons, use of an MLE or BTV, and graphical comparisons. If survey data are consistent with NORM or anthropogenic background, site conditions comply with the Parcel G ROD RAO.
  - If any result is greater than the RG and cannot be attributed to NORM or anthropogenic background, remediation will be conducted.
- **Step 7-Develop the Plan for Obtaining Data:** Radiological investigations will be conducted on floors, wall surfaces, and ceiling surfaces, and will consist of alpha and beta scan surveys, alpha-beta static measurements, and alpha-beta swipe samples as described herein.

4.2 Radionuclides of Concern

The ROCs for Parcel G buildings, as identified in the HRA and in subsequent investigations, include ^{137}Cs, ^{60}Co, ^{239}Pu, ^{226}Ra, ^{90}Sr, and ^{232}Th and are presented in **Table 4-1**.

Table 4-1. Building Radionuclides of Concern

Building	ROCs	Reference
Building 351	^{137}Cs, ^{226}Ra, ^{90}Sr, ^{232}Th	NAVSEA, 2004
Building 351A	^{137}Cs, ^{239}Pu, ^{226}Ra, ^{90}Sr, ^{232}Th	NAVSEA, 2004
Building 366	^{137}Cs, ^{226}Ra, ^{90}Sr	NAVSEA, 2004
Building 401	^{137}Cs, ^{226}Ra, ^{90}Sr	TtEC, 2009c
Building 408	^{137}Cs, ^{226}Ra, ^{90}Sr, ^{232}Th	NAVSEA, 2004
Building 411	^{137}Cs, ^{60}Co, ^{226}Ra	NAVSEA, 2004
Building 439	^{137}Cs, ^{226}Ra	TtEC, 2009a

4.3 Remediation Goals

The building data from the radiological investigations will be evaluated to determine whether site conditions are compliant with the RAO in the Parcel G ROD (Navy, 2009). The RAO is to prevent exposure to ROCs in concentrations that exceed RGs for all potentially complete exposure pathways. These RGs for structures, equipment, and waste are presented in **Table 4-2** for each of the ROCs identified for the applicable buildings. Also identified for each ROC is the primary particle type emitted during the ROC's decay or during the ROC's radioactive progeny's decay.

Table 4-2. Building Remediation Goals from Parcel G ROD

ROC	Particle Emissions	RGs for Structures (dpm/100 cm^2)	RGs for Equipment, Waste (dpm/100 cm^2)
^{137}Cs	β	5,000	5,000
^{60}Co	β	5,000	5,000
^{239}Pu	α	100	100
^{226}Ra	α, β	100	100
^{90}Sr	β	1,000	1,000
^{232}Th	α, β	36.5	1,000

dpm/100 cm^2 = disintegration(s) per minute per 100 square centimeters

Data collected from building surfaces during this investigation represent the total (fixed and removable) gross activity on the surface, which may result from radiations from multiple radionuclides. Because these survey data are radiation-specific (α and β) but not radionuclide-specific, they cannot be attributed to a particular ROC. Instead, the survey data will be compared to the most restrictive building-specific RG_α and RG_β as presented in **Table 4-3**. For each building, the RG_α is chosen as the structure's lowest RG for an alpha-emitting ROC, and the RG_β is chosen as the structure's lowest RG for a beta-emitting ROC.

Table 4-3. Building-specific Remediation Goals for Parcel G Work Plan

Building	RG_α (dpm/100 cm^2) and ROC	RG_β (dpm/100 cm^2) and ROC
Building 351	36.5 (^{232}Th)	1,000 (^{90}Sr)
Building 351A	36.5 (^{232}Th)	1,000 (^{90}Sr)
Building 366	100 (^{226}Ra)	1,000 (^{90}Sr)
Building 401	100 (^{226}Ra)	1,000 (^{90}Sr)
Building 408 slab	36.5 (^{232}Th)	1,000 (^{90}Sr)
Building 411	100 (^{226}Ra)	5,000 (^{137}Cs)
Building 439	100 (^{226}Ra)	5,000 (^{137}Cs)

4.4 Radiological Investigation Design

This section describes the design of radiological investigations, including scan and static measurements on building surfaces. The radiological investigation design is based on methods, techniques, and instrument systems in the Basewide Radiological Management Plan (TtEC, 2012), with the ultimate requirement to demonstrate compliance with the Parcel G ROD RAO.

The principal features of the investigation protocol to be applied to the Parcel G building SUs are discussed herein and include the following:

- Determine the SUs.
- Select survey instruments.
- Determine instrument ILs and MDCs.

To the extent possible, manual data entries will be eliminated through use of electronic data collection and transfer processes.

4.4.1 Building Survey Overview

The radiological surveys of the impacted Parcel G buildings have two primary components (scanning measurements and static measurements), which are discussed in subsections 4.4.1.1 and 4.4.1.2. In addition, swipe samples will be collected to assess potential gross alpha and beta removable contamination. If needed, swipe samples will be analyzed offsite to speciate the radionuclides present. Building material samples may be collected and analyzed offsite to characterize areas of interest identified by the surveys.

4.4.1.1 Scanning Measurements

Scanning measurements are performed on building surfaces to locate radiation anomalies indicating residual radioactivity that may require further investigation or remediation. As noted in **Section 4.3**, the scanning design is dictated by the most restrictive RG_{α} and RG_{β} values for the building. Where appropriate, scanning measurements will be performed using the assumptions of equilibrium described in **Section 4.5.5**.

4.4.1.2 Static Measurements

Static measurements will be the primary means of demonstrating compliance with the Parcel G ROD RAO. Gross alpha and beta static measurements will be performed so that the measurement MDC is below the most restrictive RG_{α} and RG_{β} values for the building.

Static measurements will be performed in each SU and in the RBAs. They will consist of measurements in scaler mode for simultaneous alpha-beta counting using a Ludlum Model 43-68 gas proportional detector, Ludlum Model 43-93 plastic scintillation detector, or other appropriate instrument. While 1-minute count times were used in the following example calculations, static count times will be updated during investigations to meet DQOs using instrument-specific information. Static measurements will be performed on a systematic sampling grid or biased to locations identified by the alpha-beta scanning surveys.

The number of systematic static measurements performed will be based on the guidance described in MARSSIM Sections 5.5.2.2 and 5.5.2.5 (USEPA et al., 2000) using the unity rule as the example basis for calculating the minimum static measurement frequency. Even if the MARSSIM-recommended or other statistical tests are not used to evaluate site data, these calculations serve as a basis for determining the number of static measurements per SU to be performed. The number of biased static measurements will be determined based on results of scan surveys.

MARSSIM Section 5.5.2.2 defines the method for calculating the number of static measurements when residual radioactivity is uniformly present throughout an SU. Therefore, determining the number of static measurements will be based on the following factors:

- RG for radioactivity on structural surfaces (UBGR)
- LBGR
- Estimate of variability (standard deviation [σ]) in the reference area and the SUs
- Shift (Δ=UBGR-LBGR)
- Relative shift ([UBGR-LBGR]/σ); see **Equation 4-1**
- Decision error rates for making a Type I or Type II decision error that the mean or median concentration exceeds the RG (determined via MARSSIM Table 5.2)

Each of the preceding factors is addressed in the following paragraphs. Example data are provided to assist in explaining the process for calculating the minimum static measurement frequency. Actual numbers of static measurements for SUs will be based on reference area data once they become available. When using the unity rule, the RG is defined as 1 (unitless) plus background. As a basis for the calculations, the background surface activity concentration is assumed to be 0.5.

MARSSIM defines a gray region as the range of values in which the consequences of decision error on whether the residual surface activity is less than or exceeds the RG are relatively minor. The RG of 1 above background (0.5) was selected to represent the UBGR (1.5). The LBGR is the median concentration in the SU, and the retrospective power will be determined after the survey is completed. Given the absence of usable data prior to performing the investigation activities, MARSSIM Section 2.5.4 suggests arbitrarily selecting the LBGR as half the RG. Therefore, for this example, the LBGR = 0.5 + 0.5 = 1. Assuming the UBGR equals the RG, then Δ = 1.5 – 1.0 = 0.5 for this example.

MARSSIM defines σ as an estimate of the standard deviation of the measured values in the SU. Because SU data will not be available until the investigation activities are completed, MARSSIM recommends using the standard deviation of the RBA as an estimate of σ. Given the absence of data prior to performing the investigation activities, an arbitrary value of 0.25 has been selected as an estimate of σ for this example.

The relative shift is calculated based on MARSSIM guidance (Section 5.5.2.2) as shown in **Equation 4-1.**

Equation 4-1

$$\frac{\Delta}{\sigma} = \frac{(UBGR - LBGR)}{\sigma} = \frac{(RG - LBGR)}{\sigma} = \frac{(1.5 - 1.0)}{0.25} = 2.0$$

The minimum number of samples assumes the ROC concentration in the SU exceeds the RG. Type I decision error is deciding that the ROC concentration in the SU is less than the RG when it actually exceeds the RG. To minimize the potential for releasing buildings with concentrations above the RG, the Type I decision error rate is set at 0.01. Type II decision error is deciding that the ROC concentration exceeds the RG when it is actually less than the RG. To protect against remediating building surfaces with concentrations below the RG, the Type II decision error rate is set at 0.05 as recommended by MARSSIM.

MARSSIM Table 5.3 lists the minimum number of static measurements to be performed in each SU and RBA based on the relative shift and decision error rates. For a relative shift of 2, a Type I decision error rate at 0.01, and Type II decision error rate of 0.05, MARSSIM Table 5.3 recommends a minimum of 18 static measurements in each SU and RBA.

Therefore, 18 static measurements are recommended as a placeholder until background data are available. The minimum number of static measurements per SU will be developed based on the variability observed in the RBA data. The DQA of SU data will include a retrospective power curve (based on the MARSSIM Appendix I guidance) to demonstrate that enough static measurements were performed to meet the project objectives. If necessary, additional static measurements may be performed to comply with the project objectives.

4.4.2 Radiological Background

Building 404 will serve as the primary RBA in the investigation of Parcel G buildings (**Figure 4-1**). Building 404 is a non-impacted, unoccupied former supply storehouse constructed in 1943 (see Reference 1598 in NAVSEA, 2004). From the same construction era and with materials similar to those of the impacted Parcel G buildings, Building 404 has 43,695 square feet of concrete floors, a wooden superstructure, prepared roll or composition roof, and drywall offices.

At least 18 static measurements will be taken on each surface material in the RBA that is representative of the material in the building SUs. Alternate RBAs may be identified and used if needed based on site-specific conditions identified during the building investigations.

4.4.3 Survey Units

Parcel G buildings will be divided into identifiable SUs similar in area and nomenclature to the previous investigation of each building. **Table 4-4** lists the SUs, classification, and areas by building. Generally, impacted floor surfaces and the lower 2 meters of remaining impacted wall surfaces will form Class 1 SUs of no more than 100 m^2 each. The remaining impacted upper wall surfaces and ceilings will generally form Class 2 SUs of no more than 2,000 m^2 each. Class 3 SUs consist of floor areas in Building 411 and the exterior of Building 366, which were investigated as part of past scoping surveys.

Several buildings on HPNS were remediated for lead and asbestos. This resulted in most of the interior wall and ceiling surfaces being removed, leaving only the wall structural components (i.e., wooden or metal framing). Areas with known releases have been remediated and recovered during past investigations such that there are no areas of suspected surface or volumetric contamination remaining in Parcel G buildings. This investigation measures only the remaining, accessible and impacted surfaces through a combination of scanning, static, and swipe measurements. The SU designations and floor boundaries will remain the same as those used in the historical TtEC investigations; however, the overall survey area will be reduced by the amount of area remediated for lead-based paint and asbestos.

The floor plans and floor SUs are shown for each building on **Figures 4-2** through **4-8**. Two example figures are provided that depict SU-specific details for a Class 1 SU (**Figure 4-10**) and a Class 2 SU (**Figure 4-11**). **Figure 4-10** is a two-dimensional representation of Building 366 (SU 1) and shows the Class 1 floors, remaining lower wall surfaces, and intended static measurement and swipe sample locations. **Figure 4-11** is a two-dimensional representation of Building 366 (SU 60) and shows the Class 2 upper walls, ceiling, and intended static measurement and swipe sample locations.

Additional building-specific information regarding the Parcel G buildings is provided in the following paragraphs and in **Table 4-4**.

4.4.3.1 Building 351A

There are 40 Class 1 SUs (SUs 1 to 3, 5 to 14, 16, 18 to 27, and 29 to 44) consisting of concrete flooring and concrete (perimeter and SU 6 interior) lower walls (**Figure 4-2**). There are three Class 2 SUs (SUs 45 to 47), which divide all the concrete perimeter upper walls and the concrete ceiling in SU 6. There are no other remaining ceilings. SUs 4, 15, 17, and 28 were originally surveyed by TtEC but incorporated into other SUs during past investigations and are no longer present.

The limiting alpha-emitting ROC for the Building 351A scans is ^{239}Pu, and for Building 351A static measurements is ^{232}Th. The limiting beta-emitting ROC is ^{90}Sr.

4.4.3.2 Building 351

There are 11 Class 1 SUs on the first floor (SUs 1 to 11) consisting of concrete flooring, concrete support columns, concrete perimeter lower walls, and asphalt cover over remediation trenches (**Figure 4-3**). There are 20 Class 1 SUs on the second floor (SUs 17 to 36) consisting of concrete flooring, concrete support columns, and concrete perimeter lower walls. There are no remaining interior lower wall surfaces on the first or second floors. There are 10 Class 1 SUs on the third floor (SUs 42 to 51) consisting of concrete flooring, concrete support columns, concrete perimeter lower walls, and metal interior lower walls around SU 45. There are five Class 2 SUs (SUs 39, 40, and 52 to 54). SU 39 is the Class 2 SU formed by the first floor concrete ceiling and concrete (perimeter) upper walls. SU 40 is the Class 2 SU formed by the second floor concrete ceiling and concrete (perimeter) upper walls. SU 52 is the Class 2 SU formed by the third floor concrete ceiling and concrete (perimeter) or metal (SU 45 interior) upper

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walls. SU 53 consists of the Class 2 areas with the stairwells, and SU 54 consists of the Class 2 floor, walls, and ceiling within the elevator. SU designations 12 to 16, 37, 38, and 41 were originally surveyed by TtEC but incorporated into other SUs during past investigations and are no longer present.

The limiting alpha-emitting ROC for Building 351 is ^{232}Th, and the limiting beta-emitting ROC is ^{90}Sr.

4.4.3.3 Building 366

There are 45 Class 1 SUs (SUs 1 to 14, 18, 24 to 28, 31 to 38, and 43 to 59) consisting of concrete flooring and sheet metal (perimeter) or sheetrock (interior) lower walls (**Figure 4-4**). SU designations 15 to 17, 19 to 23, 29 and 30, and 39 to 42 were originally surveyed by TtEC but incorporated into other SUs during past investigations and are no longer present. There are nine Class 2 SUs (SUs 60 to 68) and one Class 3 SU (SU 69). SUs 60 to 63 divide the metal roof and perimeter metal upper walls into four Class 2 SUs. SUs 64 and 65 are the Class 2 areas formed by the metal gables at the building's western and eastern ends. SUs 66 to 68 are the Class 2 faces of metal firewalls in place on three roof trusses. The building exterior (SU 69) is a Class 3 SU.

The limiting alpha-emitting ROC for Building 366 is ^{226}Ra, and the limiting beta-emitting ROC is ^{90}Sr.

4.4.3.4 Building 401

There are 26 Class 1 SUs on the first floor (SUs 1 to 22 and 32 to 35) consisting of concrete flooring, wooden or concrete perimeter lower walls, and sheetrock interior lower walls (**Figure 4-5**). There are seven Class 1 SUs on the second floor (SUs 24-29 and 36) consisting of wooden or metal flooring and wooden perimeter lower walls. There are no remaining impacted, interior lower wall surfaces on the second floor. SUs 30 and 31 divide the first floor upper walls and ceilings into two Class 2 SUs consisting of wood paneled, sheetrock, or wooden upper walls and the undersides of the second floor's wooden or metal floors. The upper walls and ceilings of the second floor, as well as the remaining of the building, were not considered impacted by the tenant's storage of gauges and were not previously surveyed. Portions of the second floor SUs include wooden flooring that is highly deteriorated and may not be safely accessible for survey.

The limiting alpha-emitting ROC for Building 401 is ^{226}Ra, and the limiting beta-emitting ROC is ^{90}Sr.

4.4.3.5 Building 408

The remaining concrete slab of the former building (**Figure 4-6**) will be investigated as a single Class 1 SU. A Class 2 buffer area (SU 2) surrounding the Class 1 SU will also be surveyed.

The limiting alpha-emitting ROC for Building 408 is ^{232}Th, and the limiting beta-emitting ROC is ^{90}Sr.

4.4.3.6 Building 411

There are five Class 1 SUs on the first floor (SUs 5 to 7 and 9 and 10) consisting of concrete flooring (**Figure 4-7**). Class 1 SUs are surrounded by two Class 2 SUs (SUs 8 and 11) consisting of concrete flooring and lower walls. The ground level floor surfaces surrounding the Class 2 SUs form two Class 3 SUs (SUs 3 and 4) consisting of concrete flooring or steel grating. SU 3 and SU 4 contain many deep and water-filled pits/sumps that were not previously surveyed because of safety and accessibility concerns. SU 2 forms a single Class 3 SU on the second floor and consists of concrete flooring. The third floor and mezzanine are no longer accessible because of concerns about structural stability; therefore, the Class 3 SU 1 that was previously surveyed by TtEC is not included in this investigation. Access points to that area will be included with surveys of adjacent SUs.

The limiting alpha-emitting ROC for Building 411 is ^{226}Ra, and the limiting beta-emitting ROC is ^{137}Cs.

4.4.3.7 Building 439

The radiologically impacted area within Building 439 is an enclosed area that was historically leased to Young Laboratories. The original survey area consisted of two Class 1 SUs (SU 1 and SU 2) on the floors and lower walls of the enclosure, and a Class 2 SU (SU 3) on the enclosure's upper walls and ceiling (**Figure 4-8**). After remediation was performed in a small area within SU 1, a new Class 1 SU (SU 4) was established within the remediated area. In addition, two Class 2 SUs were established as buffer areas within the enclosure and in a 2-meter perimeter on the outside of the enclosure (SUs 5 and 6, respectively). Because of the overlap of the pre- and post-remediation SUs, the investigation at Building 439 will consist of Class 1 surveys in SUs 1 and 2, and Class 2 surveys in SUs 3 and 6. The Class 1 survey in SU 1 will capture areas previously surveyed as SUs 4 and 5.

The limiting alpha-emitting ROC for Building 439 is ^{226}Ra, and the limiting beta-emitting ROC is ^{137}Cs.

4.4.4 Reference Coordinate System

Survey unit scan lanes and static measurement locations will be marked using a consistent reference coordinate system throughout the building. In the absence of other technologies, locations will reference from the southernmost and westernmost points in the SU.

4.5 Instrumentation

Investigation data will be collected using position-sensitive proportional counters (PSPCs), gas proportional counters, and swipe sample counters as described herein.

4.5.1 Position-sensitive Proportional Counters

Large area surface scanning and static measurements for alpha and beta radiations will be performed using PSPCs such as the Radiation Safety and Control Services, Inc. (RSCS) Surface Contamination Monitor (SCM) or equivalent instrument. The RSCS SCM simultaneously acquires alpha-beta data from motor-controlled dual detectors moving over a surface at a fixed rate between 1.25 and 12.5 centimeters per second (cm/s). Detector functions, movement, and response are controlled through a Survey Information Management System (SIMS). The SIMS is also used to log, display, and interpret investigation data and generate survey reports. The detectors are configured in parallel and the system can identify the location of each reading within 5 cm along a detector's length. Operated in rolling (dynamic) mode for scanning, the SCM acquires data for each 5 cm of detector width and every 5 cm of forward travel. The data for the resulting 25-square-centimeter (cm^2) area is binned, then combined as one-fourth of the overall 100 cm^2 response.

4.5.2 Gas Proportional Detectors

Gas proportional detectors, such as the large area Ludlum Model 43-37, small area Ludlum Model 43-68, or equivalent instruments, will be used for scanning measurements in areas that are not accessible to or practicable for the RSCS SCM. The Ludlum Model 43-37 detector physical size is 2.5 by 15.9 by 46.4 cm (H by W by L) with an active area of 584 cm^2. The Ludlum Model 43-68 is 10 by 11.7 by 19.8 cm, with an active area of 126 cm^2. Scanning speed is surveyor-controlled, and data are automatically logged when used with an appropriate data-logging scaler/ratemeter, such as the Ludlum Model 2360 or equivalent. The Ludlum Model 43-68 may also be used to perform static measurements.

4.5.3 Scintillation Detectors

Alpha-beta scintillation detectors may also be used for scanning and static measurements. The Ludlum Model 43-93 has an active detector area of 100 cm^2 and simultaneously counts alpha radiation using a zinc sulfide scintillator and beta radiation using a thin plastic scintillator.

4.5.4 Alpha-Beta Sample Counter

Swipe samples to assess removable activity will be performed using an alpha-beta plastic scintillation counter, such as the Ludlum Model 3030 Alpha-Beta Sample Counter or equivalent. The Ludlum Model 3030 has an active detector area of 20.3 cm^2 and simultaneously counts alpha-beta radiation from 5.1 cm swipe papers loaded into a single sample tray.

4.5.5 Instrument Efficiencies

Manufacturer-provided parameters are provided in **Table 4-5**, including the detector physical (active) areas, detector widths in the direction of scanning, total (4π) efficiencies, and background count rates. These parameters will be updated during the investigation for each instrument used.

Table 4-5. Typical Survey Instrument Efficiencies and Background Count Rates from Manufacturers

Parameter	RSCS SCM	Ludlum Model 43-37	Ludlum Model 43-68	Ludlum Model 43-93	Ludlum Model 3030
Type of Measurement	**Scanning**	**Scanning**	**Scanning/Static**	**Scanning/Static**	**Smear Counting**
Detector active area, *A* (cm^2)	100	584	126	100	20.3
Width in direction of scan, *d* (cm)	20	13.335	8.8	6.94	NA
Alpha total efficiency (4π) for ^{239}Pu		0.175	0.175	0.20	0.37
Alpha total efficiency (4π) for ^{235}U	NA	NA	NA	NA	0.39
Alpha total efficiency (4π) for ^{230}Th		NA	NA	NA	0.32
Alpha total efficiency (4π) for ^{226}Ra	0.188	NA	NA	NA	NA
Beta total efficiency (4π) for ^{99}Tc		0.20	0.20	0.15	0.27
Beta total efficiency (4π) for $^{90}Sr/^{90}Y$	0.90	0.20	0.20	0.20	0.26
Beta total efficiency (4π) for ^{137}Cs		NA	NA	NA	0.29
Alpha background (cpm)	1	< 10	≤ 3	≤ 3	≤ 3
Beta background (cpm)	636	800 - 1300	350	≤ 300	≤ 50

Notes:
^{90}Y = yttrium-90
^{99}Tc = technetium-99
< = less than
≤ = less than or equal to
NA = not applicable

The response of a detector to the incident radiations from building surfaces differs from the values in **Table 4-5** depending on the presence and state of equilibrium of radioactive progenies. Of the ROCs in **Table 4-1**, ^{226}Ra, ^{90}Sr, and ^{232}Th have radioactive progenies that emit alpha or beta particles during their decay. The concentration of each progeny relative to its parent depends on its parent's decay fraction and the equilibrium fraction of the entire series or chain. ^{226}Ra and ^{232}Th both have radon isotopes as progeny. Because both radon (^{222}Rn) and thoron (^{220}Rn) are gases, a fraction of their concentration may escape the building area before decaying, and the relative abundance (equilibrium fraction) of the subsequent progenies is reduced. For the ^{226}Ra decay series, the radon decay products typically have a 0.4 equilibrium fraction indoors (see Question 17 in USEPA, 2014) such that the progeny of radon (^{222}Rn) is only present at 40 percent of the ^{222}Rn concentration. Similarly, for the ^{232}Th decay series, the radon decay products typically have a 0.02 equilibrium fraction indoors (see Question 17 in USEPA, 2014) such that the progeny of thoron (^{220}Rn) is only present at 2 percent of the ^{220}Rn concentration.

In **Table 4-6**, each ROC and its progeny is listed along with the associated type of particle emitted during decay, the fraction of times that particle type is emitted, the radon decay product abundance relative to ^{222}Rn or ^{220}Rn, and the 4-π efficiencies and 4-π weighted efficiencies for the three example detector types for building investigations. The 4-π weighted efficiencies for each radionuclide and detector is the product of its decay fraction, equilibrium fraction, and 4-π efficiency. The total alpha (or beta) 4-π weighted efficiencies for ^{226}Ra, ^{90}Sr, and ^{232}Th are the summed alpha (or beta) 4-π weighted efficiencies of themselves and their progeny. To illustrate, the alpha response (4-π efficiency) of the RSCS SCM to pure ^{226}Ra is 0.188 (or 18.8 counts per 100 disintegrations of ^{226}Ra). However, ^{226}Ra exists in partial equilibrium with its radioactive progeny, and for each disintegration of ^{226}Ra, there are 3.2 alpha particles and 1.6 beta particles formed. The resultant total alpha 4-π weighted efficiency for the RSCS SCM and the ^{226}Ra chain is 0.188 x 3.2 = 0.602. Consistent with Section 4.3.2 of MARSSIM (USEPA et al., 2000), the weighted efficiencies provided in **Table 4-6** are used for the instrument sensitivity calculations described in the remainder of this section.

Table 4-6. Detector Efficiencies for Each ROC and Alpha- or Beta-emitting Progeny

				4π Efficiencies (Estimated)					4π Weight	
Parent ROC and Alpha- or Beta-emitting Progenies	Particle Emission	Decay Fraction	Equilibrium Fraction	RSCS SCM	Ludlum Model 43-37	Ludlum Model 43-68	Ludlum Model 43-93	Ludlum Model 3030	RSCS SCM	Ludlum Model 43-37
^{137}Cs	Beta	1.00	1.00	0.900	0.200	0.200	0.200	0.290	0.900	0.200
^{60}Co	Beta	1.00	1.00	0.900	0.200	0.200	0.150	0.270	0.900	0.200
^{239}Pu	Alpha	1.00	1.00	0.188	0.175	0.175	0.200	0.370	0.188	0.175
^{226}Ra	Alpha	1.00	1.00	0.188	0.175	0.175	0.200	0.320	0.188	0.175
^{222}Rn	Alpha	1.00	1.00	0.188	0.175	0.175	0.200	0.370	0.188	0.175
^{218}Po	Alpha	1.00	0.40	0.188	0.175	0.175	0.200	0.370	0.075	0.070
^{214}Pb	Beta	1.00	0.40	0.900	0.200	0.200	0.200	0.260	0.360	0.080
^{214}Bi	Beta	1.00	0.40	0.900	0.200	0.200	0.200	0.260	0.360	0.080
^{214}Po	Alpha	1.00	0.40	0.188	0.175	0.175	0.200	0.370	0.075	0.070
^{210}Pb	Beta	1.00	0.40	0	0	0	0	0	0	0
^{210}Bi	Beta	1.00	0.40	0.900	0.200	0.200	0.200	0.260	0.360	0.080
^{210}Po	Alpha	1.00	0.40	0.188	0.200	0.175	0.200	0.370	0.075	0.080
		Total ^{226}Ra alphas	***3.20***						***0.602***	***0.570***
		Total ^{226}Ra betas	***1.60***						***1.080***	***0.240***
^{90}Sr	Beta	1.00	1.00	0.900	0.200	0.200	0.200	0.260	0.900	0.200
^{90}Y	Beta	1.00	1.00	0.900	0.200	0.200	0.200	0.260	0.900	0.200
		Total ^{90}Sr betas	***2.00***						***1.800***	***0.400***
^{232}Th	Alpha	1.00	1.00	0.188	0.175	0.175	0.200	0.390	0.188	0.175
^{228}Ra	Beta	1.00	1.00	0.900	0	0	0	0	0	0

Table 4-6. Detector Efficiencies for Each ROC and Alpha- or Beta-emitting Progeny

				4π Efficiencies (Estimated)					4π Weig	
Parent ROC and Alpha- or Beta-emitting Progenies	Particle Emission	Decay Fraction	Equilibrium Fraction	RSCS SCM	Ludlum Model 43-37	Ludlum Model 43-68	Ludlum Model 43-93	Ludlum Model 3030	RSCS SCM	Ludlu Mod 43-3
^{228}Ac	Beta	1.00	1.00	0.900	0.200	0.200	0.200	0.260	0.1088	0.20
^{228}Th	Alpha	1.00	1.00	0.188	0.175	0.175	0.200	0.370	0.188	0.17
^{224}Ra	Alpha	1.00	1.00	0.188	0.175	0.175	0.200	0.370	0.188	0.17
^{220}Rn	Alpha	1.00	1.00	0.188	0.175	0.175	0.200	0.370	0.188	0.17
^{216}Po	Alpha	1.00	0.02	0.188	0.175	0.175	0.200	0.370	0.004	0.00
^{212}Pb	Beta	1.00	0.02	0.900	0.200	0.200	0.150	0.270	0.018	0.00
^{212}Bi	Beta	0.64	0.02	0.900	0.200	0.200	0.200	0.260	0.012	0.00
	Alpha	0.36	0.02	0.188	0.175	0.175	0.200	0.370	0.001	0.00
^{212}Po	Alpha	1.00	0.02	0.188	0.175	0.175	0.200	0.370	0.004	0.00
^{208}Tl	Beta	1.00	0.02	0.900	0.200	0.200	0.200	0.260	0.018	0.00
	Total ^{232}Th alphas		***4.05***						***0.761***	***0.70***
	Total ^{232}Th betas		***2.05***						***0.948***	***0.21***

Notes:

Total alphas or betas = sum of (decay fraction x equilibrium fraction)

^{208}Tl = thallium-208

^{210}Bi = bismuth-210

^{210}Pb = lead-210

^{210}Po = polonium-210

^{212}Bi = bismuth-212

^{212}Pb = lead-212

^{212}Po = polonium-212

^{214}Pb = lead-214

^{214}Po = polonium-214

^{216}Po = polonium-216

^{218}Po = polonium-218

^{224}Ra = radium-224

^{228}Ac = actinium-228

^{228}Ra = radium-228

^{228}Th = thorium-228

4.5.6 Calibration

Portable survey instruments will be calibrated annually at a minimum, in accordance with ANSI N323 (ANSI, 1997), or an applicable later version. Instruments will be removed from service on or before calibration due dates for recalibration. If ANSI N323 does not provide a standard method, the calibration facility should comply with the manufacturer's recommended method.

4.5.7 Daily Performance Checks

Before using the portable survey instruments, calibration verification, physical inspection, battery check, and source-response check will be performed in accordance with SOP RP-108, *Count Rate Instruments*, and SOP RP-109, *Dose Rate Instruments* (**Appendix D**). Portable survey instruments will have a current calibration label that will be verified daily before use.

Physical inspection of the portable survey instrument will include the following:

- General physical condition of the instrument and detector before each use
- Knobs, buttons, cables, connectors
- Meter movements and displays
- Instrument cases
- Probe and probe windows
- Other physical properties that may affect the proper operation of the instrument or detector

Any portable survey instrument or detector having a questionable physical condition will not be used until problems have been corrected. A battery check will be performed to ensure that sufficient voltage is being supplied to the detector and instrument circuitry for proper operation. This check will be performed in accordance with the instrument's operations manual. The instrument will be exposed to the appropriate (alpha or beta) check source, to verify that the instrument response is within the plus or minus 20 percent range determined during the initial response check. The calibration certificates and daily QA/QC records for each instrument used and the instrument setup test records will be provided in the project report.

If any portable survey instrument, or instrument and detector combination, having a questionable physical condition that cannot be corrected fails any of the operation checks stated in SOP RP-108, *Count Rate Instruments*, or SOP RP-109, *Dose Rate Instruments* (**Appendix D**), or has exceeded its annual calibration date without PRSO approval, the instrument will be put in an "out of service" condition. This is done by placing an "out of service" tag or equivalent on the instrument and securing the instrument or the instrument and detector combination in a separate area such that the instrument and instrument and detector combination cannot be issued for use. The PRSO and RCTs and their respective supervisors will be notified immediately when any survey instrumentation has been placed "out of service." Instruments tagged as "out of service" will not be returned to service until all deficiencies have been corrected. The results of the daily operation checks, discussed above, will be documented.

4.5.8 Instrument Detection Calculations and Investigation Levels

Instrument-specific parameters used for building investigations are calculated in the following sections. These include the average scan rate, ILs, alpha detection probabilities and MDCs for scanning measurements and the ILs and MDCs for static measurements. These calculations will be updated during building investigations (**Section 4.6.3**) using information from calibration sheets and background measurements for each instrument.

4.5.8.1 Scan Rate

While scanning, the period that a moving detector spends above an area of elevated activity, or the dwell time (in seconds), depends on the rate of scanning (cm/s) and the size of the area of elevated activity (cm^2). The detector dwell time (t) is also called the detector residence time or observation interval (i) in some references. The size of any area of elevated activity cannot be known before investigation, so the conventional approach is to assume a typical size for the area (e.g., 100 cm^2) and choose a scan rate that provides a reasonable value for t. Generally, dwell times in the 0.5- to 2-second range are considered reasonable. If the 100 cm^2 area of elevated activity is 10 cm x 10 cm, then these dwell times would result in average detector scan rates, ν, between 5 and 20 cm/s.

Average scan rates for each instrument used for scanning will be determined during instrument preparations (**Section 4.6.3.1**) to meet required detection sensitivities. Movement of a PSPC, such as the RSCS SCM, is motor-controlled and has a fixed scan rate, ν, which is typically between 1.25 and 12.5 cm/s. Movement of other large area detectors, such as the Ludlum Model 43-37, is surveyor-controlled and the average scan rate will be monitored during scanning and verified during data evaluation.

4.5.8.2 Scan Investigation Levels

Scan data are compared to scan ILs. ILs are instrument-, ROC-, and surface material-specific surface activity levels, in units of the instrument's response (cpm). Scan data that exceed an applicable scan IL will be investigated using biased measurements (**Section 4.6.3.4**). Scan ILs will be updated during instrument preparations (**Section 4.6.3.1**).

The measurements for alpha and beta surface activity occur simultaneously during scanning; however, the signal detection theory for alpha emitters differs greatly from that of beta emitters. Surface conditions and other factors result in relatively low probabilities that alpha particles emitted from sources on a surface will reach the detector, while beta scanning provides a more reliable and efficient method for the detection of beta emitters. Given that ^{226}Ra and ^{232}Th have progeny that emit beta particles, the collection of beta scanning measurements will supplement and verify alpha scans where ^{226}Ra and ^{232}Th are ROCs.

Scan ILs are calculated using **Equation 4-2** and the detector-specific information in **Table 4-5** and **Table 4-6**. To enable direct comparison to the alpha ratemeter output during scanning, the RG for each alpha-emitting ROC is converted from units of dpm/100 cm^2 to cpm (beta) using **Equation 4-2**, which is based on the discussion of data conversion in MARSSIM Section 6.6.1 (USEPA et al., 2000). The beta scan IL is determined in a similar manner.

Equation 4-2

$$\text{Scan IL}_{(\alpha \text{ or } \beta)}\ (\text{cpm}) = RG_{(\alpha\ or\ \beta)} \cdot \varepsilon_{T\,(\alpha\ or\ \beta)} \cdot \left(\frac{A}{100\ cm^2}\right) + R_{B\,(\alpha\ or\ \beta)}$$

Where:

$RG_{(\alpha \text{ or } \beta)}$		= remediation goal for alpha- or beta-emitting ROC (dpm/100 cm^2)
$\varepsilon_{T\,(\alpha\ or\ \beta)}$		= detector total (4-π) efficiency (counts per disintegration)
A		= detector probe physical (active) area (cm^2)
$R_{B\,(\alpha\ or\ \beta)}$		= alpha or beta background count rate (cpm)

For illustration, calculated scan ILs are presented in **Table 4-7** for each ROC and for three detector models. Site-specific scan ILs will be determined during instrument preparations (**Section 4.6.3.1**).

<u>Example</u>: ^{232}Th alpha scan IL for the RSCS SCM.

$$\text{Scan IL}^{232}Th_{,\alpha}\ (\text{RSCS SCM}) = 36.5 \cdot 0.761 \cdot \left(\frac{100}{100}\right) + 1 = 28.8\ cpm$$

Where:

$RG^{232}Th_{,\alpha}$	= 36.5 dpm/100 cm^2
$\varepsilon_{T,\alpha}$	= 0.761 (total weighted efficiency for ^{232}Th)
A	= 100 cm^2 (combined area of four 25 cm^2 bins)
$R_{B,\alpha}$	= 1 cpm

Table 4-7. Preliminary Instrument Scan Investigation Levels

ROC	RSCS SCM (cpm)		Ludlum 43-37 (cpm)		Ludlum 43-68 (cpm)	
	Alpha	Beta	Alpha	Beta	Alpha	Beta
^{137}Cs	NA	5,136	NA	6,890	NA	1,435
^{60}Co	NA	5,136	NA	6,890	NA	1,435
^{239}Pu	19	NA	107	NA	23	NA
^{226}Ra	61	780	337	1,190	72	205
^{90}Sr	NA	2,436	NA	3,386	NA	679
^{232}Th	28	703	159	1,095	34	184

Notes:

NA = not applicable

4.5.8.3 Probability of Alpha Detection for High-background Detectors

The measurements for alpha and beta surface activity occur simultaneously during scanning; however, the signal detection theory for alpha emitters differs greatly from that of beta emitters. For alpha scanning, one verifies that while scanning at rate v, there is a specified probability (typically 90 percent) that surface activity present at the RG_{α} will be detected.

Equation 4-3 (adapted from Equation 6-14 in MARSSIM [USEPA et al., 2000]) is used for detectors having higher background rates (i.e., 5 to 10 cpm) to determine the probability of recording at least two alpha counts, $P(n \geq 2)$, while passing over an area contaminated at the RG_{α}, during t. It is assumed that all the elevated activity is contained in a 100 cm^2 area and that the detector passes over the area in one or multiple scan passes.

To achieve the sensitivity needed to detect alpha-emitting ROCs at the release criteria, where possible the SCM will be used in the coincidence, with two detectors hard-mounted to each other at a set distance. The system will be operated at a target speed of 2.5 to 5 cm/s, with the detector approximately 0.5 inch from the surface. The probability of detecting two or more counts due to a source at the RG_{α} is given by Equation 4-3 (Equation 6-14 from MARSSIM [USEPA et al., 2000]), as follows:

Equation 4-3

$$P(n \geq 2) = 1 - \left(1 + \frac{(GE+B)t}{60}\right)\left(e^{\frac{-(GE+B)t}{60}}\right)$$

Where:

$P(n \geq 2)$	=	probability of getting two or more counts during the time interval t (percent)
t	=	time interval (seconds)
G	=	contamination activity (disintegrations per minute [dpm]) = equal to the RG_{α}
E	=	total efficiency (4-pi)
B	=	background count rate (cpm)

Because the detectors associated with the SCM are manufactured to the same specifications, the efficiency of each detector is similar. Therefore, the probability of obtaining two or more counts on each detector as they traverse the same source (assumed to be 36.5 dpm for the purposes of this calculation) is the square of the probability for a single detector.

Typical alpha background values observed with the SCM are less than 5 cpm/100 cm^2. The total detector efficiency (4-pi) of the SCM for the alpha emission from ^{232}Th is assumed to be 0.761, according to **Table 4-6**. The detector width is 20 cm in the direction of travel. Survey speed for alpha emitters is 2.5 cm/s (1 inch per second), resulting in a dwell time of 8 seconds. Using these parameters, **Equation 4-3** is solved as follows:

$$P(n \geq 2) = 1 - \left(1 + \frac{(36.5 \times 0.761 + 5)8}{60}\right)\left(e^{\frac{-(36.5 \times 0.761 + 5)8}{60}}\right) = 93.2\%$$

Where:

$P(n \geq 2)$	=	probability of getting two or more counts during the time interval t
t	=	8 seconds
G	=	36.5 dpm
E	=	0.761 (total weighted efficiency for ^{232}Th alphas from **Table 4-6**)
B	=	5 cpm

As calculated above, the probability of getting two or more counts during the SCM observation interval of 4 seconds when surveying a 36.5-dpm hotspot is equal to 93.2 percent at a scan speed of 2.5 cm/s. Alpha detection probabilities and associated scan speeds for large area detectors will be updated as needed during survey preparation (**Section 4.6.3.1**) to reflect instrument-, ROC-, and surface material-specific information.

4.5.8.4 Probability of Alpha Detection for Small Area Detectors

The alpha count rate on various surfaces will average approximately 2 cpm with a small area Ludlum Model 43-68 detector. When using a 126 cm^2 or smaller detector, scanning for alpha emitters differs because the expected background response of most alpha detectors is close to zero. A single count in the defined residence time will result in a second measurement of equal duration. One or more additional counts will require investigation with a static measurement as described in **Section 4.6.3.4**.

The probability of detecting given levels of alpha surface contamination for smaller detectors can be calculated by use of Poisson summation statistics. Given a known measurement interval and a surface contamination release limit, the probability of detecting a single count for the measurement interval to be used during this project and sample data from a typical Ludlum Model 43-68 setup is given by Equation 6-12 of MARSSIM (USEPA et al., 2000), shown as **Equation 4-4**:

Equation 4-4

$$P(n \geq 1) = 1 - e^{\frac{-(GEd)}{60v}}$$

Where:

P(n ≥ 1)	=	probability of observing a single count
G	=	contamination activity = RG_α
E	=	total efficiency (4-pi)
d	=	width of detector in direction of scan (cm)
v	=	scan speed (cm/s)
B	=	background count rate

Equation 4-4 may be solved as follows:

$$P(n \geq 1) = 1 - e^{\frac{-(36.5 \times 0.708)8.8}{60x2.5}} = 78.1\%$$

Where:

$P(n \geq 1)$	=	probability of observing a single count
G	=	36.5 dpm
E	=	0.708 (**Table 4-6**)
d	=	8.8 cm
v	=	5 cm/s

As calculated above, the probability of getting one or more counts during a Ludlum Model 43-68 scan moving at 2.5 cm/s when surveying a 36.5-dpm hotspot is equal to 78.1 percent. Alpha detection probabilities and associated scan speeds for small area detectors will be updated as needed during survey preparation (**Section 4.6.3.1**) to reflect instrument-, ROC-, and surface material-specific information.

4.5.8.5 Beta Scan Minimum Detectable Concentration

The rate at which each detection instrument traverses across the surface being surveyed is necessarily detector- and radionuclide-specific and varies with accepted error rates, surveyor efficiency, and surface beta background. We assume that 95 percent true positive ($\alpha = 0.95$) and 5 percent false positive ($\beta = 0.95$) rates are required, such that $d' = 3.28$ from MARSSIM Table 6.5. A value of 0.5 for p, the surveyor efficiency, is typical for surveyor-controlled detectors and 1.0 for motor-controlled detectors. The β scan MDC is calculated using **Equation 4-5** (adapted from MARSSIM, Equation 6-10 [USEPA et al., 2000]). Instruments will be selected for scanning to ensure that their beta scan MDC is less than or equal to the RG_β for the building from **Table 4-3**. **Equations 4-5** through **4-7** are derived as follows:

Equation 4-5

$$\beta\ scan\ MDC\ (\text{dpm}/100\ \text{cm}^2) = \frac{MDCR}{\sqrt{p} \cdot \varepsilon_{i,\beta} \cdot \varepsilon_{s,\beta} \cdot \dfrac{A}{100\ cm^2}}$$

Where:

$MDCR$	= minimum detectable count rate
p	= surveyor efficiency
$\varepsilon_{i,\beta}$	= detector (2-π) beta efficiency (counts per disintegration)
$\varepsilon_{s,\beta}$	= surface (2-π) beta efficiency (counts per disintegration)
A	= detector physical (active) area (cm²)

Substituting $MDCR = 60{\cdot}s_i/i$ (MARSSIM Equation 6-9), $t = i$, $s_i = d'{\cdot}(b_i)^{1/2}$ (MARSSIM Equation 6-8) and $\varepsilon_{T,\beta} = \varepsilon_{i,\beta} \cdot \varepsilon_{s,\beta}$ yields **Equation 4-6:**

Equation 4-6

$$\beta\ scan\ MDC\ (\text{dpm}/100\ \text{cm}^2) = \frac{60 \cdot s_i/t}{\sqrt{p} \cdot \varepsilon_{T,\beta} \cdot \dfrac{A}{100\ cm^2}} = \frac{60 \cdot d' \cdot \sqrt{b_i}/t}{\sqrt{p} \cdot \varepsilon_{T,\beta} \cdot \dfrac{A}{100\ cm^2}}$$

Where:

s_i	= minimum detectable net source counts in t
d'	= index of sensitivity (for error rates α and β)
b_i	= background counts in t
t	= d/v = detector dwell time (seconds)
d	= width of detector in direction of scan (cm)
v	= average scan rate (cm/s)
$\varepsilon_{T,\beta}$	= detector total (4-π) beta efficiency (counts per disintegration)

Substituting $b_i = R_{B,\beta}\ (\text{cpm}){\cdot}t\ (\text{seconds})/60$ yields **Equation 4-7**:

Equation 4-7

$$\beta\ scan\ MDC\ (\text{dpm}/100\ \text{cm}^2) = \frac{d' \cdot \sqrt{R_{B,\beta} \cdot \frac{t}{60}} \cdot \frac{60}{t}}{\sqrt{p} \cdot \varepsilon_{T,\beta} \cdot \frac{A}{100}}$$

Where:

$R_{B,\beta}$ = background beta count rate (cpm)

The beta scan MDCs for each scan survey instrument and ROC are presented in **Table 4-8** for various detector average scan rates.

***<u>Example</u>**: Beta Scan MDC Calculation for the RSCS SCM.*

The β scan MDC is calculated for the RSCS SCM scanning for beta emitters at 5 cm/s and using the parameters presented in **Table 4-5** and **Table 4-6**. Because the scan rate is motor-controlled and there are no scanning pauses, the surveyor efficiency, *p*, is 100 percent.

$$\beta\ \text{scan MDC (RSCS SCM},\ ^{137}\text{Cs}) = \frac{3.28 \cdot \sqrt{636 \cdot \frac{4.0}{60}} \cdot \frac{60}{4.0}}{\sqrt{1.0} \cdot 0.900 \cdot \frac{100}{100}} = 356.0\ \text{dpm}/100\ \text{cm}^2$$

Where:

d' = 3.28 (for 95% true positive and 5% false positive)

$R_{B,\beta}$ = 636 cpm

t = d/v = 20 cm/(5 cm/s) = 4 seconds

p = 1

$\varepsilon_{T,\beta}$ = 0.900 for beta emitters

A = 100 cm^2

Table 4-8. Beta Scan Minimum Detectable Concentrations (dpm/100 cm^2) at 5 cm/s

	Scan Rate (5 cm/s)	
ROC	**RSCS SCM**	**Ludlum Model 43-37**
^{137}Cs	356	610
^{60}Co	356	610
^{226}Ra	297	509
^{90}Sr	178	305
^{232}Th	338	580

Table 4-8 demonstrates that at a scan rate for the RCSC SCM of 5 cm/s, the beta scan MDCs for all ROCs are below the most restrictive RG_β (1,000 dpm/100 cm^2 for ^{90}Sr) for both large area survey instruments. Beta scan MDCs and associated scan speeds will be updated as needed during survey preparation (**Section 4.6.3.1**) to reflect instrument-, ROC-, and surface material-specific information.

4.5.8.6 Static Investigation Levels

Static measurement data are compared to static ILs. Static measurement data that exceed an applicable static IL will be investigated using biased measurements (**Section 4.6.3.4**).

The alpha and beta static ILs are determined using the static measurement count time in **Equation 4-8**, which is based on the discussion of data conversion in MARSSIM Section 6.6.1 (USEPA et al., 2000). Static ILs will be updated as needed during survey preparation (**Section 4.6.3.1**) using instrument-, ROC- and surface material-specific information.

Equation 4-8

$$\text{Static IL}_{(\alpha \text{ or } \beta)} \text{ (counts)} = \left[RG_{(\alpha\ or\ \beta)} \cdot \varepsilon_{T(\alpha\ or\ \beta)} \cdot \left(\frac{A}{100\ cm^2}\right) + R_{B(\alpha\ or\ \beta)}\right] \cdot T_{S+B}$$

Where:

$RG_{(\alpha \text{ or } \beta)}$	= remediation goal for alpha- or beta-emitting ROC (dpm/100 cm^2)
$\varepsilon_{T(\alpha\ or\ \beta)}$	= detector total (4-π) efficiency (counts per disintegration)
A	= detector probe physical (active) area (cm^2)
$R_{B(\alpha\ or\ \beta)}$	= alpha or beta background count rate (cpm)
T_{S+B}	= SU static counting time (minutes)

For illustration, the following example calculates the alpha static IL equivalent to the ^{232}Th RG for the Ludlum Model 43-93, on concrete, using a 1-minute static count time.

***<u>Example</u>**: Alpha static IL for the Ludlum Model 43-93*

$$\text{Static IL}_{\alpha}\left(\text{Ludlum Model 43-93, } {}^{232}Th\right) = \left[36.5 \cdot 0.200 \cdot \left(\frac{100}{100}\right) + 1\right] \cdot 1 = 8.3 \text{ counts}$$

Where:

$RG^{232}Th,_{\alpha}$	= 36.5 dpm/100 cm^2
$\varepsilon_{T,\alpha}$	= 0.200 (total efficiency for ^{232}Th, **Table 4-6**)
A	= 100 cm^2
$R_{B,\alpha}$	= 1 cpm
T_{S+B}	= 1 minute

4.5.8.7 Alpha Static Minimum Detectable Concentration

Simultaneous static alpha-beta (paired) measurements are typically taken with alpha-beta detectors coupled to scaler and ratemeter data loggers, and operated in scaler mode for the counting time, T. The division of counting times between background counting time, T_B, and SU counting time, T_{S+B}, is optimized such that the static MDCs will be less than or equal to the RG$_{\alpha}$ for the building from **Table 4-3**. The static MDC is the a priori net activity concentration above the critical level that is expected to be detected 95 percent of the time. When the count times for the background and SU measurements are different, the static MDC, for either alpha or beta activity, is calculated using **Equation 4-9** (adapted from Strom and Stansbury, 1992). Any areas of elevated activity are assumed to be 100 cm^2 in size. MDC calculations for static measurements will be updated during survey preparations (**Section 4.6.3.1**) using instrument-, ROC-, and surface material-specific information.

Equation 4-9

$$\text{Static MDC (dpm/100 cm}^2) = \frac{\left[3 + 3.29\sqrt{R_B \cdot T_{S+B} \cdot \left(1 + \frac{T_{S+B}}{T_B}\right)}\right]}{\varepsilon_T \cdot \frac{A}{100} \cdot T_{S+B}}$$

Where:

R_B	= background count rate (cpm)
T_{S+B}	= SU counting time (minutes)
T_B	= background counting time (minutes)
ε_T	= detector total (4-π) efficiency (counts per disintegration)
A	= detector probe physical (active) area (cm^2)

Instruments will be selected for static measurements to ensure that their alpha static MDC is less than or equal to the RG_α for the building from **Table 4-3.**

Example: *Alpha Static MDC Calculation for the Ludlum Model 43-93.*

The α static MDC is calculated for the Ludlum Model 43-93 using the parameters presented in **Table 4-5** and **Table 4-6**. Using **Equation 4-9**, the calculated α static MDC for ^{239}Pu is 30.8 dpm/100 cm^2.

$$\alpha\ \text{Static MDC}\left(43\text{-}93,\ ^{239}\text{Pu}\right) = \frac{\left[3 + 3.29\sqrt{2 \cdot 2 \cdot \left(1 + \frac{2}{2}\right)}\right]}{0.200 \cdot \frac{100}{100} \cdot 2} = 30.8\ \text{dpm}/100\ \text{cm}^2$$

Where:

$R_{B,\alpha}$ = 2 cpm
T_{S+B} = 2 minutes
T_B = 2 minutes
$\varepsilon_{T,\alpha}$ = 0.200
A = 100 cm^2

4.5.8.8 Beta Static Minimum Detectable Concentration

Beta static MDC calculations are also performed using **Equation 4-9** and information from **Table 4-5** and **Table 4-6**. Instruments will be selected for static measurements to ensure that their beta static MDC is less than or equal to the RG_β for the building from **Table 4-3.** MDC calculations for static measurements will be updated during survey preparations (**Section 4.6.3.1**) using instrument-, ROC-, and surface material-specific information.

The alpha and beta static MDCs for each survey instrument and ROC are presented in **Table 4-9** for 1-minute measurements in the SUs and RBAs.

Table 4-9. Instrument Static Minimum Detectable Concentrations

	Ludlum Model 43-68 (dpm/100 cm^2)		Ludlum Model 43-93 (dpm/100 cm^2)		Ludlum Model 3030 (dpm/100 cm^2)	
ROC	Alpha	Beta	Alpha	Beta	Alpha	Beta
^{137}Cs	NA	178.7	NA	225.1	NA	90.6
^{60}Co	NA	178.7	NA	300.2	NA	97.3
^{239}Pu	27.9	NA	30.8	NA	23.5	NA
^{226}Ra	27.9	148.9	30.8	187.6	7.67	84.2
^{90}Sr	NA	178.7	NA	225.1	NA	47.8
^{232}Th	27.9	169.7	30.8	214.8	5.73	95.9

Notes:
SU background static measurement count times = 2 minutes.
NA = not applicable

4.6 Radiological Investigation Implementation

Investigations will be generally implemented in the following order of activities: premobilization/mobilization, surveys, additional investigations, and demobilization.

4.6.1 Premobilization Activities

Before the start of survey activities, a walkthrough of Parcel G buildings will be completed to accomplish the following:

- Establish building access points and assess security requirements.
- Assess survey support needs such as power, lighting, ladders, or scaffolding.
- Verify the types of materials in each SU.
- Identify safety concerns and inaccessible or difficult-to-survey areas.
- Identify radiological protection and control requirements.
- Identify materials requiring removal or disposal, and areas requiring cleaning.
- Assess methods for marking survey scan lanes and static measurement locations.

Impacted areas that are deemed unsafe for access or surveys, such as the mezzanine of Building 411, will be posted, secured, and annotated in reports.

4.6.1.1 Training Requirements

Any required non-site-specific training required for field personnel will be performed before mobilization to the extent practical. Training requirements are outlined in **Section 6.**

Medical examinations, medical monitoring, and training will be conducted in accordance with the APP/SSHP and **Section 6** requirements.

In addition to health and safety-related training, other training may be required as necessary including but not limited to the following:

- Aerial Lift (for personnel working from aerial lifts)
- Fall Protection (for personnel working at heights greater than 5 feet)
- Equipment as required (e.g., fork lift, skid steer, loader, back hoe, excavator)

4.6.1.2 Permitting and Notification

Before initiation of field activities for the radiological investigations, the contractor will notify the Navy RPM, ROICC, and RASO and HPNS security as to the nature of the anticipated work. Any required permits to conduct the fieldwork will be obtained before mobilization.

The contractor will notify the California Department of Public Health at least 14 days before initiation of activities involving the Radioactive Material License.

4.6.1.3 Pre-construction Meeting

A pre-construction meeting will be held before mobilization of equipment and personnel. The purpose of the meeting will be to discuss project-specific topics, roles and responsibilities of project personnel, project schedule, health and safety concerns, and other topics that require discussions before field mobilization. Representatives of the following will attend the pre-construction meeting:

- Navy (RPM, RASO, ROICC, and others as applicable)
- Contractor (Project Manager, Site Construction Manager, Project QC Manager, PRSO, and SSHO)
- Subcontractors as appropriate

4.6.2 Mobilization Activities

Mobilization activities will include site preparation, movement of equipment and materials to the site, and orientation and training of field personnel.

At least 2 weeks before mobilization, the appropriate Navy personnel, including the Navy RPM, ROICC, and Caretaker Site Office, will be notified regarding the planned schedule for mobilization and site remediation activities. Upon receipt of the appropriate records and authorizations, field personnel, temporary facilities, and required construction materials will be mobilized to the site.

The temporary facilities will include restrooms, hand-washing stations, and one or more secure storage (Conex) boxes for short- and long-term storage of materials, if needed.

The applicable AHAs will be reviewed prior to starting work.

All equipment mobilized to the site will undergo baseline radioactivity surveys in accordance with **Section 6**. Surveys will include directs scans, static measurements, and wipe samples. Equipment that fails baseline surveying will not be removed from site immediately.

Loose, residual debris from past building occupation, investigations, vandalism, or asbestos and lead abatement will be removed for disposal and to prepare the buildings for cleaning. Cleaning will be sufficient to remove loose, surface material that may not be native to the building construction and may inhibit or damage survey instruments. Cleaning activities will be conducted consistent with the radiation protection procedures in **Section 6.4**. Dust control methods and air monitoring will be implemented, if warranted, as detailed in **Section 8.5**. Floors will be cleaned using ride-on floor scrubbers and vacuums. Walls and other surfaces will be cleaned as required during surveying. Wet areas will be dried using vacuums, blowers, or squeegees and may be delineated with spill containment booms if water infiltration is recurrent. Waste from debris removal and cleaning activities will be evaluated as described in **Section 6.4** and **Section 7**.

4.6.3 Building Investigation and Remediation Activities

Once all site preparation activities previously described are completed, building investigation and remediation activities will commence in the following general sequence:

- Mark SUs.
- Prepare instruments.
- Perform alpha-beta scanning in SUs and RBA and conduct preliminary data review.
- Perform alpha-beta systematic static and swipe measurements in SUs and RBA and conduct preliminary data review.
- Perform alpha-beta biased static and swipe measurements in SUs and conduct preliminary data review.
- Delineate and remediate residual contamination, if present.
- Evaluate and report data as described in **Section 5**.

4.6.3.1 Survey Unit Preparation

SUs will be durably marked prior to measurement activities to indicate SU boundaries, number, scan lanes and directions, and systematic measurement locations. Scan lane widths will be approximately 10 percent smaller than the detector's active width, in the direction of scanning, to ensure overlapping coverage.

Upon receipt of survey instruments for the building investigations and completion of performance checks, background measurements will be obtained in the RBAs for each instrument and on each surface material type (e.g., concrete, metal, wood, and sheet rock) that is also present in the SUs. The background measurements will consist of at least 18 static measurements on each surface to match the number performed in each SU. The mean instrument- and material-specific background count rate will be used to update the instrument detection calculations and static count times in **Section 4.5.8**.

4.6.3.2 Survey Unit and Reference Background Area Alpha-Beta Scanning

Survey units will be scanned to detect alpha and beta emitters using average scan rates that ensure an alpha probability of detection of approximately 90 percent (**Sections 4.5.8.3 and 4.5.8.4**) where feasible and that the beta scan MDC (**Section 4.5.8.5**) is less than or equal to the RG_β for the building (**Section 4.3**). Scanning will cover a total area of each SU according to its classification. The total surface area of remaining, accessible impacted surfaces to be scanned will be 100 percent in Class 1 SUs, 50 percent in Class 2 SUs, and up to 10 percent in Class 3 SUs.

The scan rate for the RSCS SCM is entered using the SIMS and results in a fixed, motor-controlled scan rate. At least every 10 SUs of scanning, the RSCS SCM scan rate will be verified manually using the distance scanned and scan duration. The distance scanned is the linear distance, in centimeters, traveled by the detector during data acquisition. The scan duration is the total time, in seconds, of data acquisition. Dividing the distance scanned (cm) by the scan duration (seconds) gives an estimate of the average detector scan rate (cm/s) for that scanning period. Direct observation or review of the positional data from the RSCS SCM serve to verify that the detector was in constant motion during scanning. The scan rates for other planned instruments (e.g., Ludlum Model 43-37 and Ludlum Model 43-68) are manually controlled by the surveyor and will be verified manually in each SU by direct observation and measurement of the time elapsed while scanning a known distance.

While using a PSPC, scanning may traverse multiple SUs at once for efficiency, but alpha-beta scan data will be assigned to, and analyzed by, individual SUs. Areas inaccessible to a PSPC will be scanned using a gas-proportional detector with data logging functions. A DQA of the alpha-beta scan data (**Section 5.2**) will identify locations that exceed the applicable beta scan IL (**Section 4.5.8.2**) and, therefore, require further investigation (**Section 5.3**). Alpha-beta scan data will also be used to verify the assumptions for the relative shift and revise the number of static measurements for each SU, if necessary (**Section 4.4.1**).

4.6.3.3 Survey Unit Systematic Alpha-Beta Static Measurements

Static measurements will be performed at each systematic static location and will total 18 in each SU and the RBA, or the revised number determined in **Section 4.4.1**. Locations that pose safety concerns or obstructions will be relocated to the nearest accessible location and noted on the field measurement forms.

Each static measurement will be performed in scaler mode for a count duration sufficient to ensure that the alpha and beta static MDCs are equal to or less than the RG_α and RG_β for the building, respectively. A DQA of the static measurement data (**Section 5.2**) will identify locations that exceed the applicable alpha or beta static IL (**Section 4.5.8.6**) and, therefore, require further investigation (**Section 5.3**) or remediation.

4.6.3.4 Biased Alpha-Beta Static Measurements

Biased static measurements will be used to further investigate areas with potential elevated surface activity, as indicated by beta scan data exceeding the beta scan IL or systematic static data exceeding the applicable alpha or beta static IL. The survey meter will be operated in scaler mode and measurements will be made for the same count duration as that for the systematic static measurements.

4.6.3.5 Alpha-Beta Swipe Samples

Swipe samples will be taken at all locations of systematic and biased static measurements. They will be taken dry, using moderate pressure, over an area of approximately 100 cm^2. Swipe samples will be measured for gross alpha and beta activity using a Ludlum Model 3030 or equivalent. The surface activity on the sample will be compared to the total surface activity measured by the static measurement to assess the removable fraction of surface activity. This information will be used in any dose or risk assessment performed.

4.6.3.6 Assessment of Residual Materials and Equipment

Several buildings contain residual materials and equipment from past operations, such as piping, ventilation, shelving, or machinery, that will undergo radioactivity surveys in accordance with SOP RP-104, *Radiological Surveys*, and SOP RP-105, *Unrestricted Release Requirements* (**Appendix D**). These surveys may include a combination of surface scans and static measurements, swipe samples, and material samples. Where possible, sampling or survey points accessed during previous surveys will be used as a starting point. Surveys of impacted building material and equipment will be incorporated into the building SU. After data evaluation, disposition decisions, and subsequent investigation of the surfaces below the materials and equipment, will be coordinated with the Navy.

4.6.3.7 Decontamination and Release of Equipment and Tools

Decontamination of mobilized materials and equipment may be necessary at completion of fieldwork if radioactive materials above RGs are encountered. Numerous decontamination methods are available for use. If practical, manual decontamination methods should be used. Abrasive methods may be necessary if areas of fixed contamination are identified. Chemical decontamination can also be accomplished by using detergents for nonporous surfaces with contamination present. Chemicals should be selected for decontamination that will minimize the creation of mixed waste. Decontamination activities will be conducted using SOP RP-132, *Radiological Protective Clothing Selection, Monitoring, and Decontamination* (**Appendix D**).

4.6.3.8 Remediation of Contaminated Building Surfaces

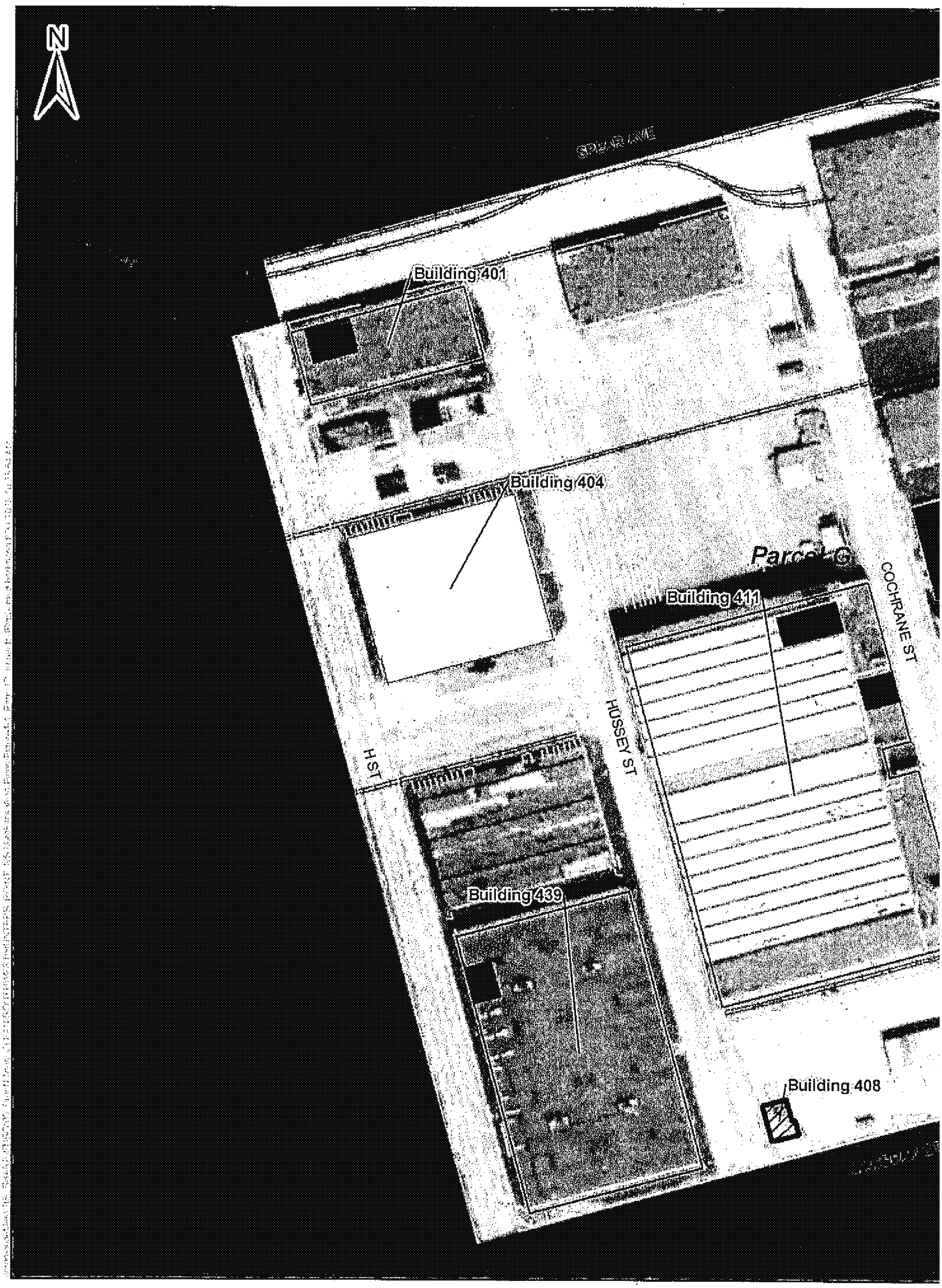
Following the identification and characterization of contaminated building surfaces, remediation may be required so that residual radioactivity meets the Parcel G ROD RAO. Specific remediation or decontamination techniques selected will depend on contaminant, type of surface, and other site-specific factors. Types of decontamination that may be performed include concrete scarifying or scabbling, application of strippable surface coatings, and bulk removal of building components. Remediation will be conducted in building areas that exceed RGs and background. Confirmation measurements will be collected where remediation is performed to verify that contamination has been removed.

4.6.4 Demobilization

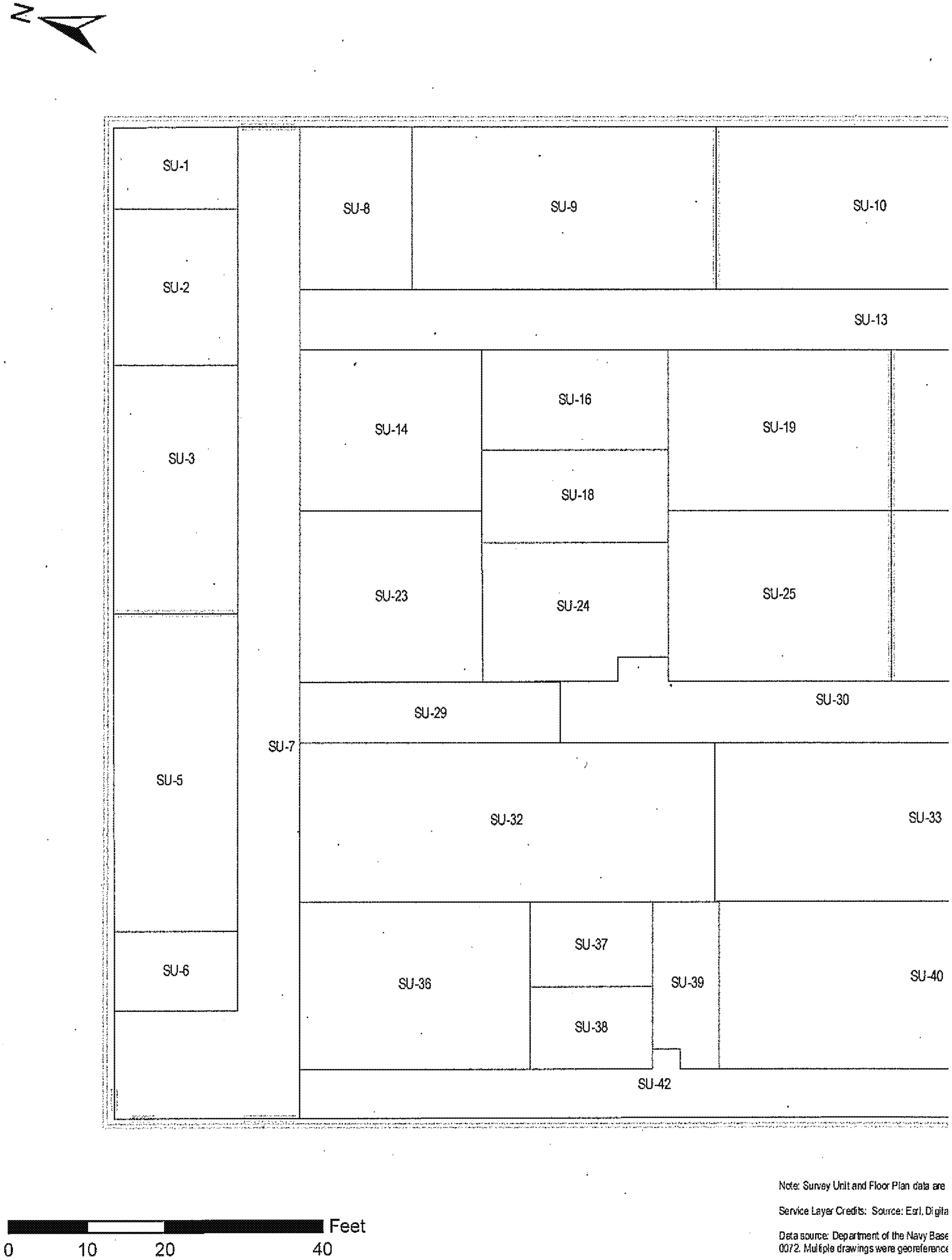
Demobilization will consist of surveying, decontaminating, and removing equipment and materials used during the investigations; cleaning and inspecting the project site; and removing temporary facilities. Survey of equipment and materials will be performed in accordance with **Section 6.6**, and decontamination will be performed in accordance with **Section 3.6.7.2**. Demobilization activities will also involve collection and disposal of contaminated materials, including decontamination water and disposable equipment for which decontamination is inappropriate (**Section 7**).

Table 4-4
Building Summary Table
Parcel G Removal Site Evaluation Work Plan
Former Hunters Point Naval Shipyard
San Francisco, California

Building	Former Uses	F
351A	Building 351A was used as a radiation detection, indication and computation repair facility and electronics shop for radiation detection equipment and a facility for the calibration, repair, and reconditioning of other instruments. The NRDL also used the building as a chemistry laboratory, applied research branch, administrative offices, nuclear and physical chemistry laboratory, and chemical technology division.	^{137}Cs, ^{239}Pu,
351	Building 351 was previously used as an electronics work area/shop, optical laboratories, Navy Bureau of Medicine and Surgery storeroom, machine shop (first floor), sampling laboratory, general research laboratories, and biological research laboratories. The NRDL also used the building as materials and accounts division, technical information division, office services branch, thermal branch, engineering division, and library.	^{137}Cs, ^{226}
366	Building 366 was used as administrative offices, applied research and technical development branches, radiological safety branch, management planning division, nucleonics division, instruments evaluation section, general laboratories, chemical research laboratory, shipyard radiography shop, boat/plastic shop, and other military/navy branch project officers station. NRDL also used the building for instrument calibration and management engineering and comptroller department.	^{137}Cs,
401	Building 401 was previously utilized as a supply storehouse, trades shop, and general stores, and by public works as a maintenance shop and offices. In 2005, the civilian tenant had been made aware of the presence of gauges and dials containing ^{226}Ra and provided the gauges and dials to the Navy.	^{137}Cs,
Former Building 408 Concrete Pad	Previously a steel-framed structure enclosing two free-standing furnaces, used for smelting, that were constructed in 1947. The building was the equivalent of three stories at its northern end, dropping to one story at its southern end, and open-sided on the north. A firebrick-lined hearth occupied most of the open area at the north. Natural gas burners were present on the east and west sides of the hearth and a pair of smokestacks extended from the lower rear segment of the building. The building has been demolished, and the concrete building pad is all that remains.	^{137}Cs, ^{226}
Building 411	Building 411 was used for source storage, as a civilian cafeteria, shipfitters and boilermakers shop, and ship repair shop. A leading enclosure measuring approximately 25 feet by 15 feet was in the building and housed an x-ray machine used for radiography.	^{137}Cs,
Building 439	Building 439 was previously used by the Navy as an equipment storage facility. Following closure of HPNS, the building was leased by a skateboard company for use as a manufacturing and assembly plant. In 2002, Young Laboratories, a civilian tenant, was relocated to a 40-foot by 50-foot enclosed area in the northwest corner of the building with a separate outside entrance. Young Laboratories processed and analyzed metals and other materials containing metals as part of its assay operations. Previous investigations in Building 364 identified an old kiln that was assumed to have been used by Young Laboratories and a subsequent survey identified slag material inside containing ^{226}Ra. Additional surveys within Building 364 identified areas of elevated ^{137}Cs activity. The Navy identified Building 439 as potentially impacted based on potential cross-contamination from Building 364 during relocation.	^{137}(


N
SPEAR AVE
Building 401
Building 404
Parcel G
Building 411
COCHRANE ST
HUSSEY ST
H ST
Building 439
Building 408

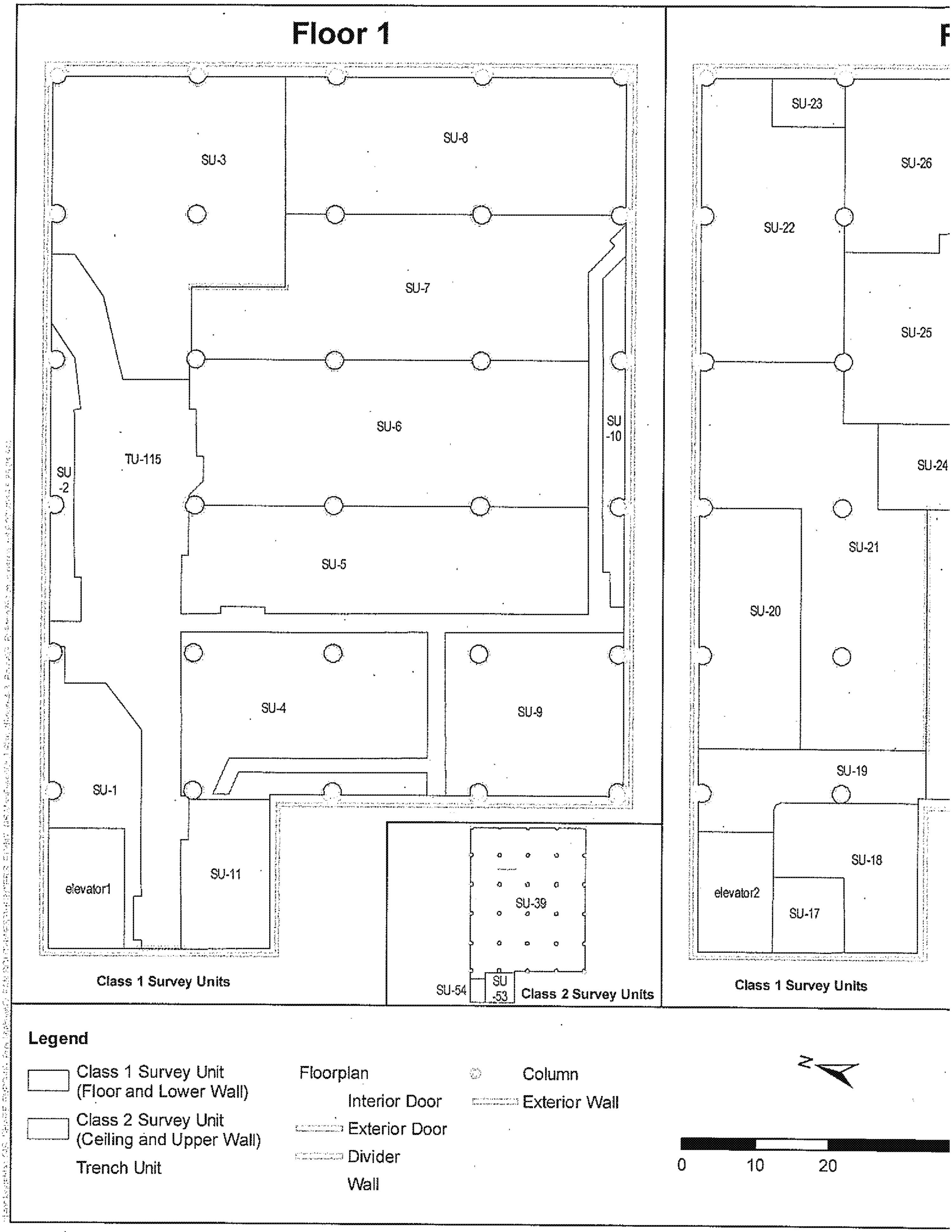
Class 1 Survey Units



Note: Survey Unit and Floor Plan data are

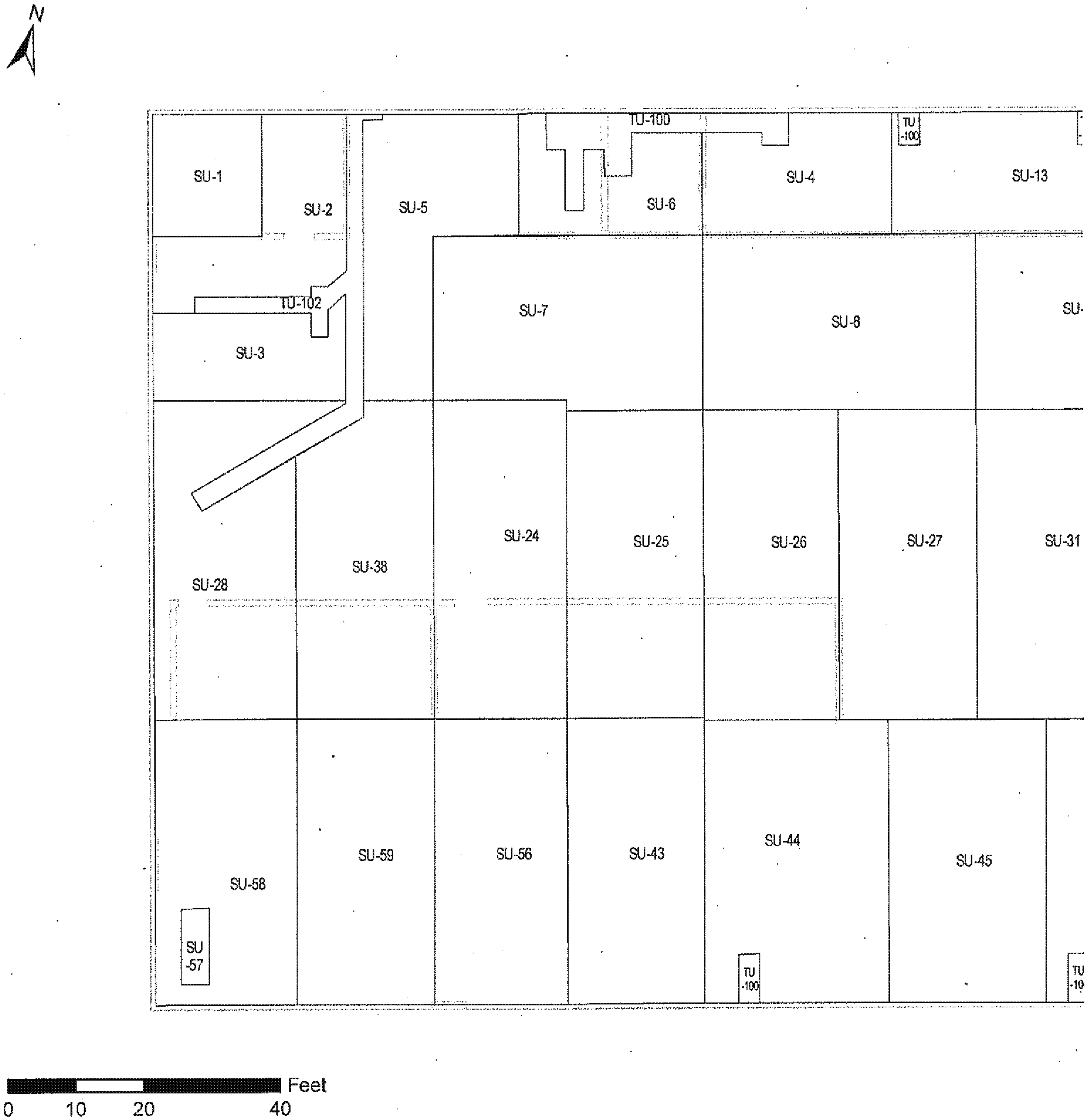
Service Layer Credits: Source: Esri, Digita

Data source: Department of the Navy Base
0072. Multiple drawings were georeference



ED_004747_00021333-00029

Class 1



Legend

Class 1 Survey Unit (Floor and Lower Wall)

Trench Unit

Class 2 Survey Unit (Ceiling and Upper Wall)

Pitched Roof

Truss

Upper Wall

Floorplans

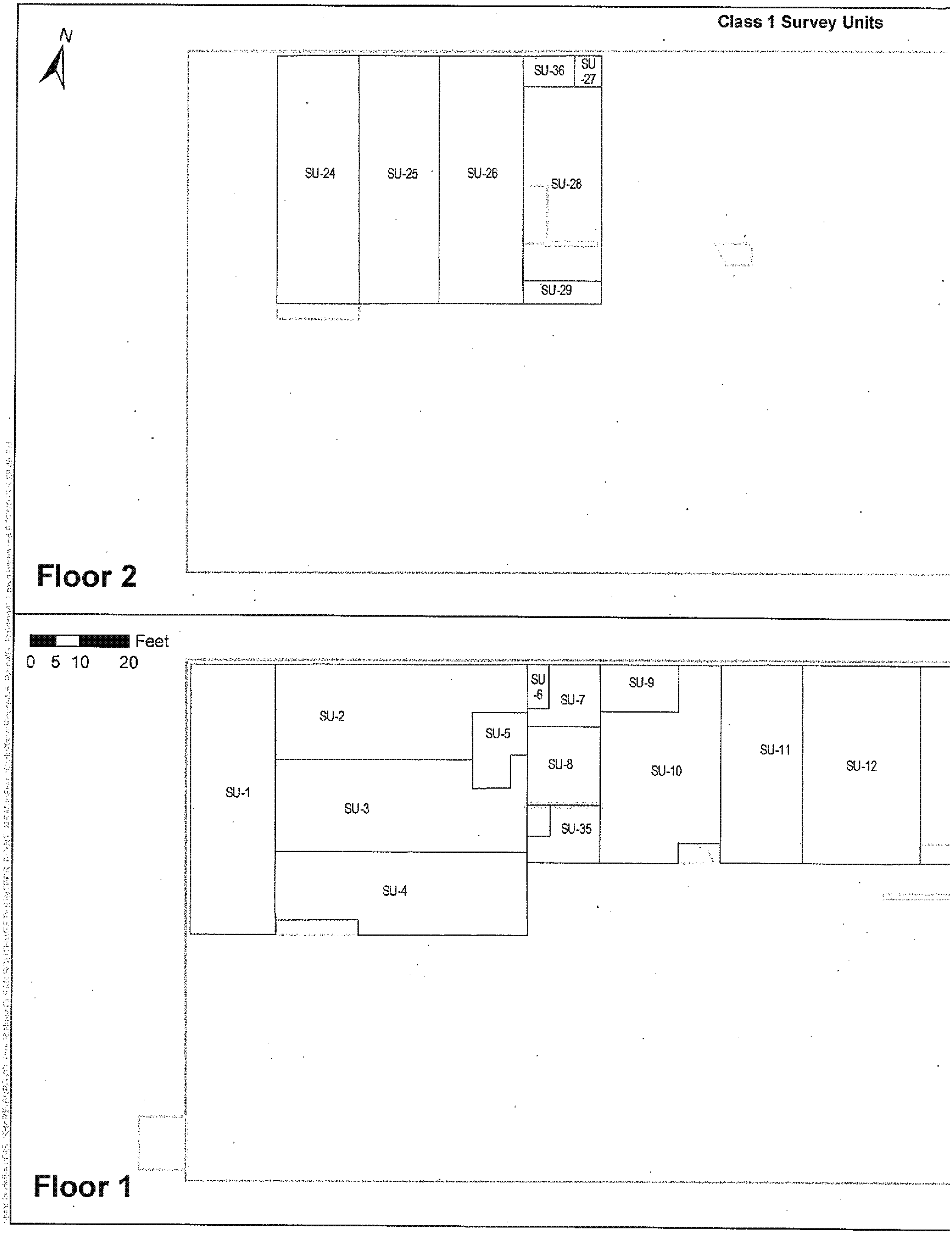
Interior Door

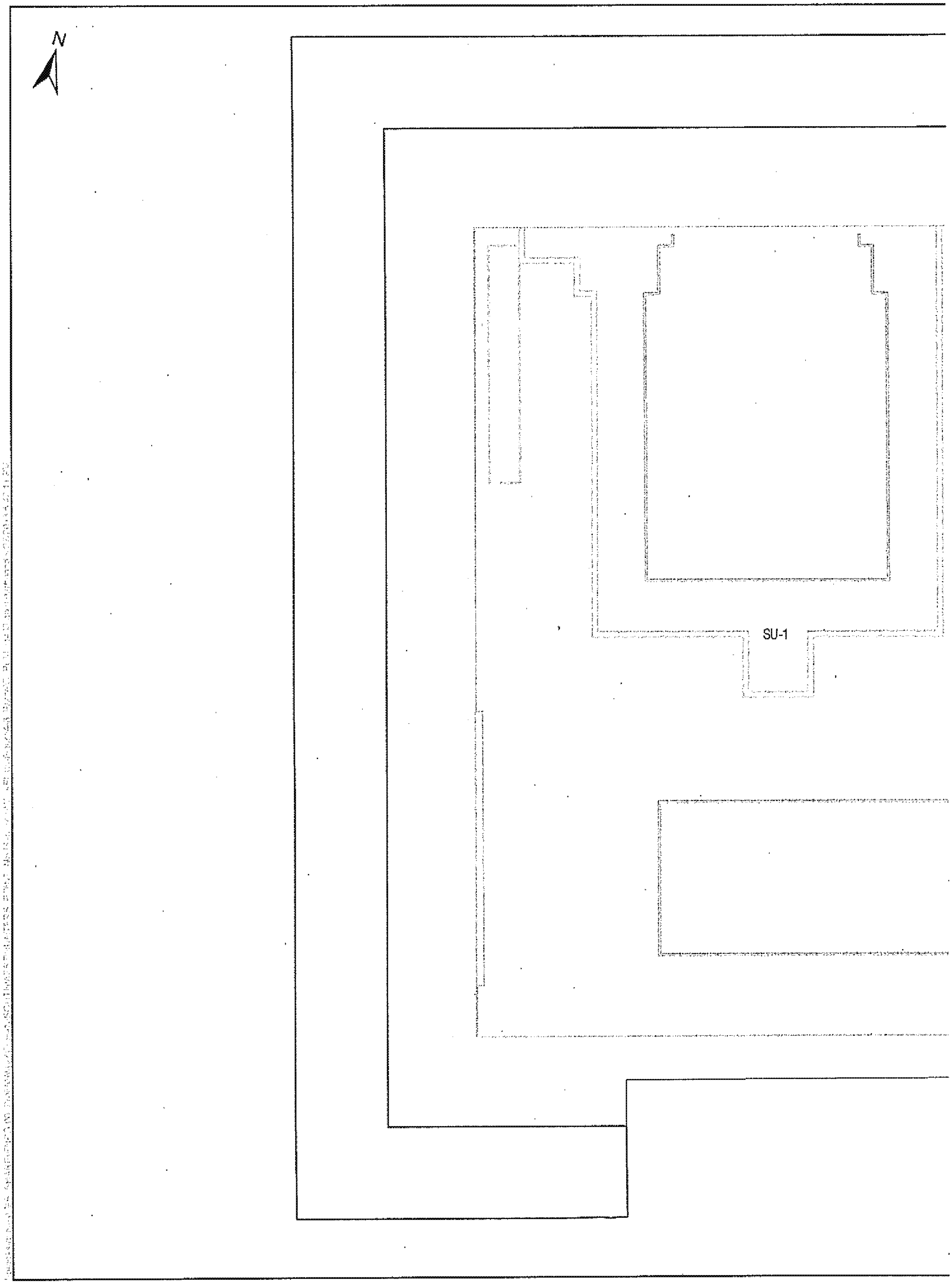
Exterior Door

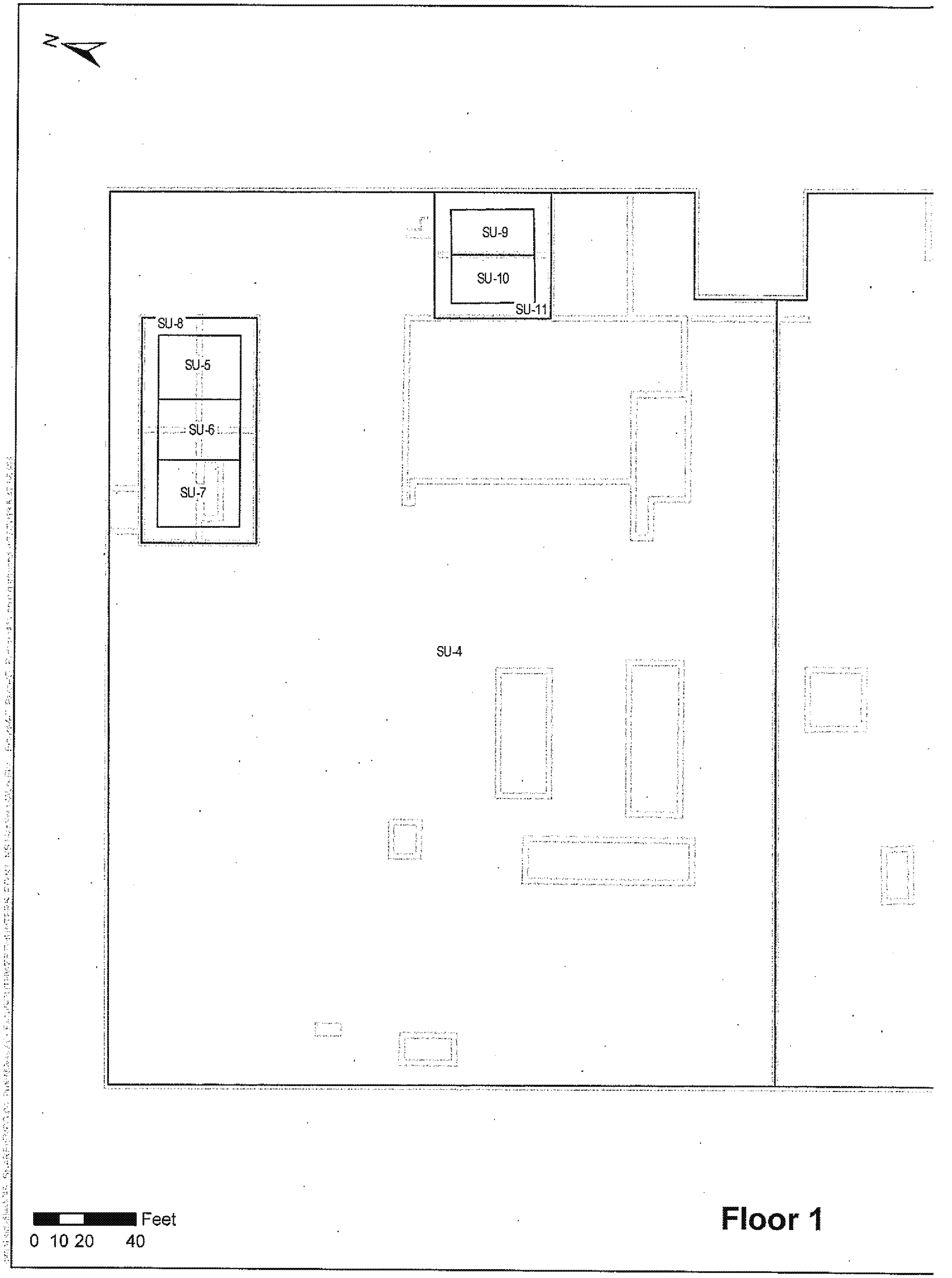
Divider

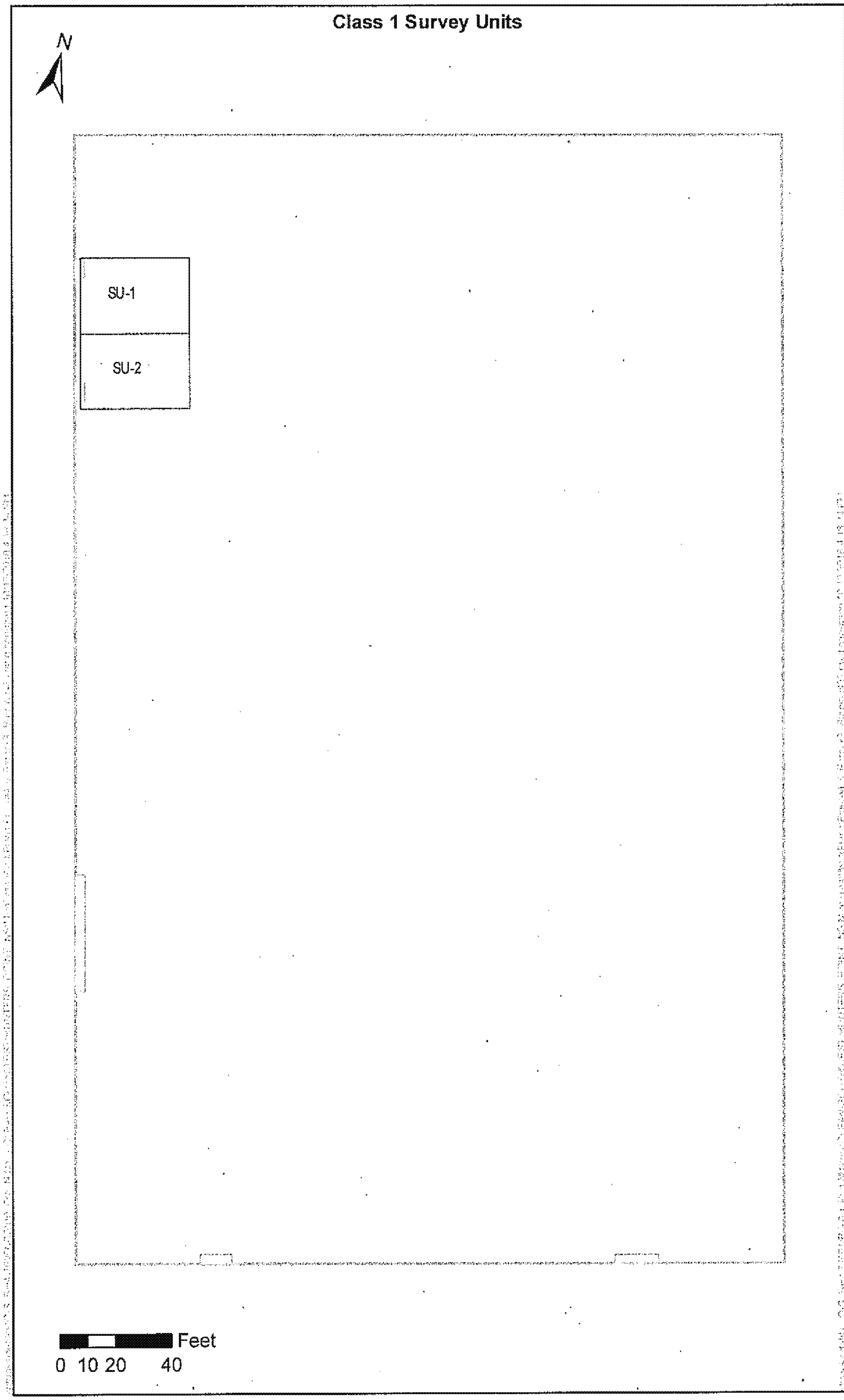
Wall

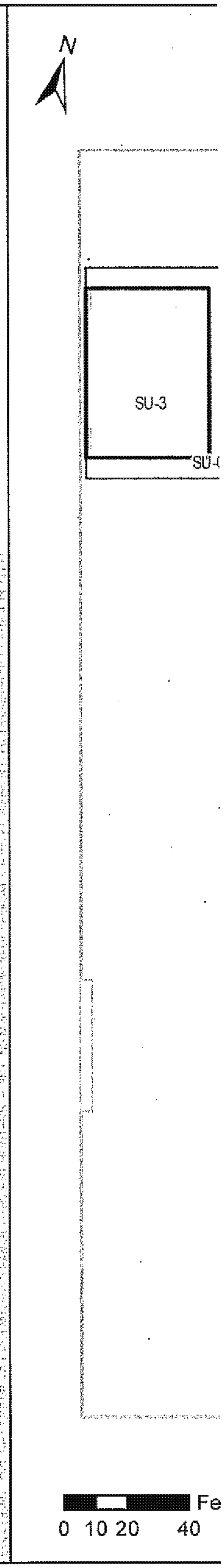
Exterior Wall

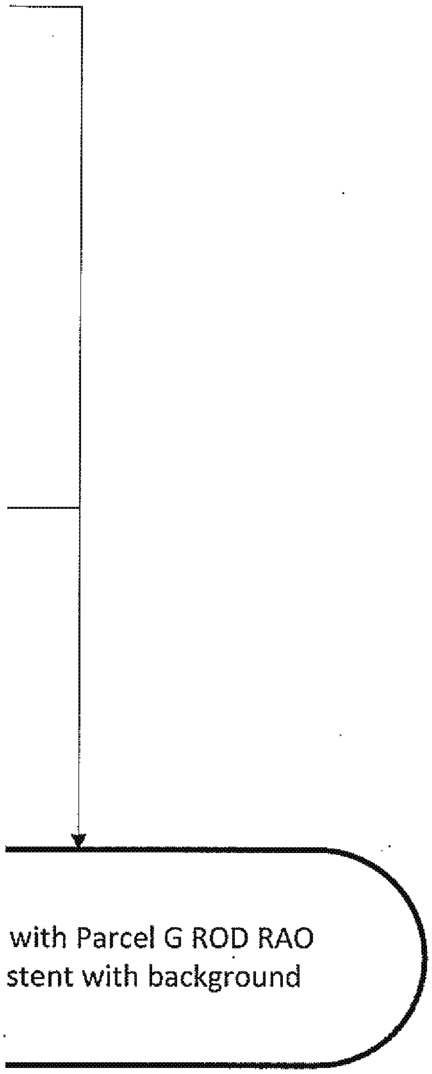

Class 1 Survey Units
N
Floor 2
SU-24
SU-25
SU-26
SU-36
SU -27
SU-28
SU-29
Feet
0 5 10 20
Floor 1
SU-1
SU-2
SU-3
SU-4
SU-5
SU -6
SU-7
SU-8
SU-9
SU-10
SU-11
SU-12
SU-35


N
SU-1


N
SU-9
SU-10
SU-11
SU-8
SU-5
SU-6
SU-7
SU-4
Feet
0 10 20 40
Floor 1


Class 1 Survey Units
N
SU-1
SU-2
Feet
0 10 20 40


N
SU-3
Fe
0 10 20 40



Acronyms:

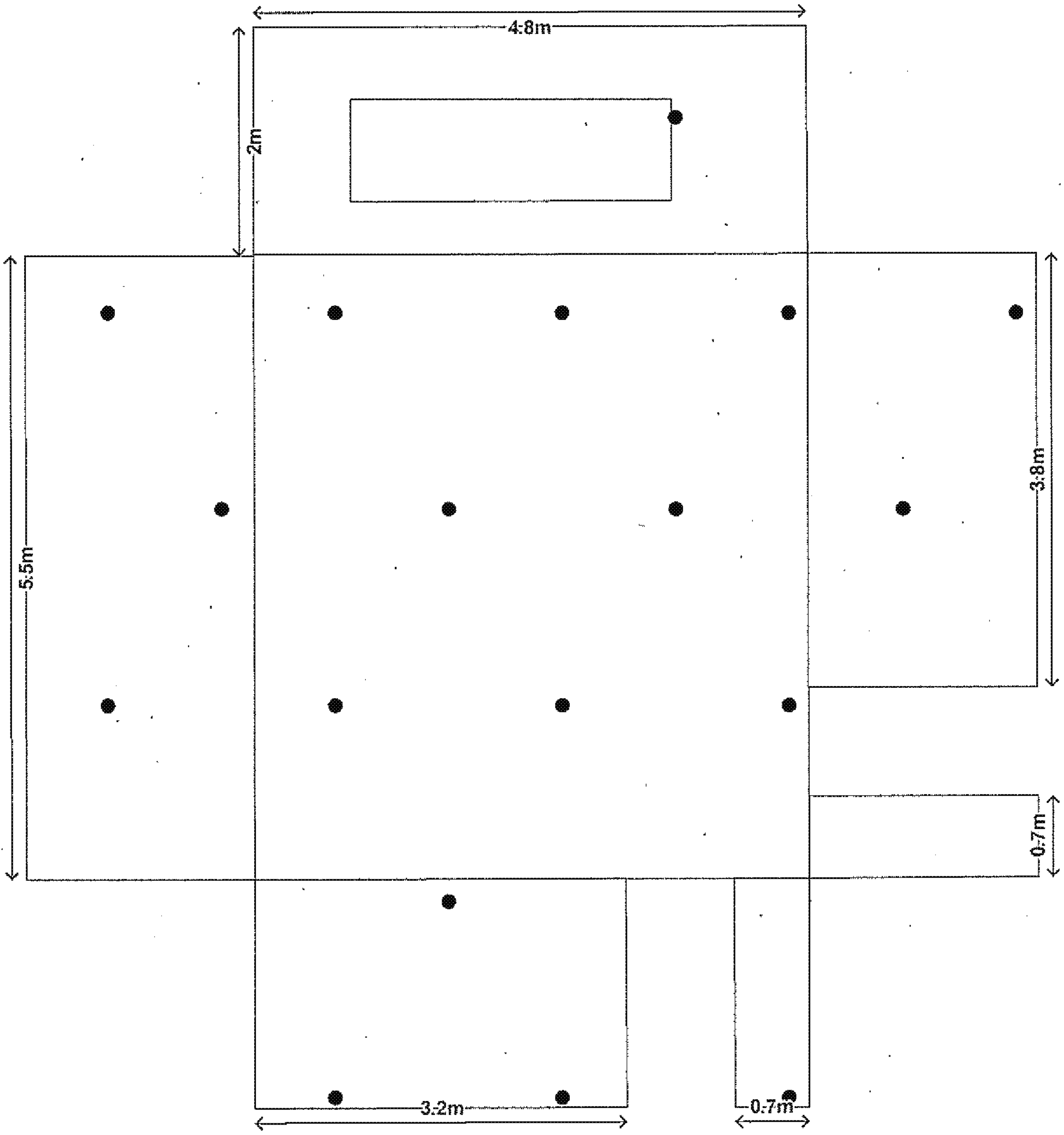
RAO = remedial action objective

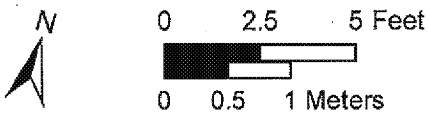
RG = remediation goal

ROD = record of decision

SU = survey unit

Figure 4-9
Performance Criteria for Demonstrating Compliance with the Parcel G ROD – Buildings
Parcel G Work Plan
Former Hunters Point Naval Shipyard
San Francisco, California



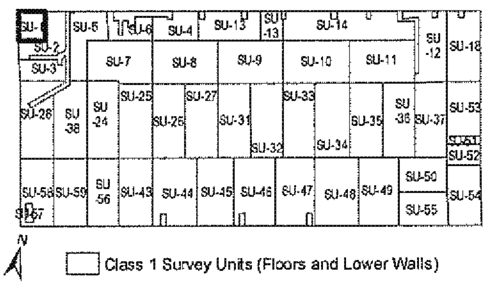


Legend

- ● Systematic Static and Swipe Location
- Estimated Wall Area* = 35 m^2
- Floor Area* = 26 m^2

Total Area* = 61 m^2

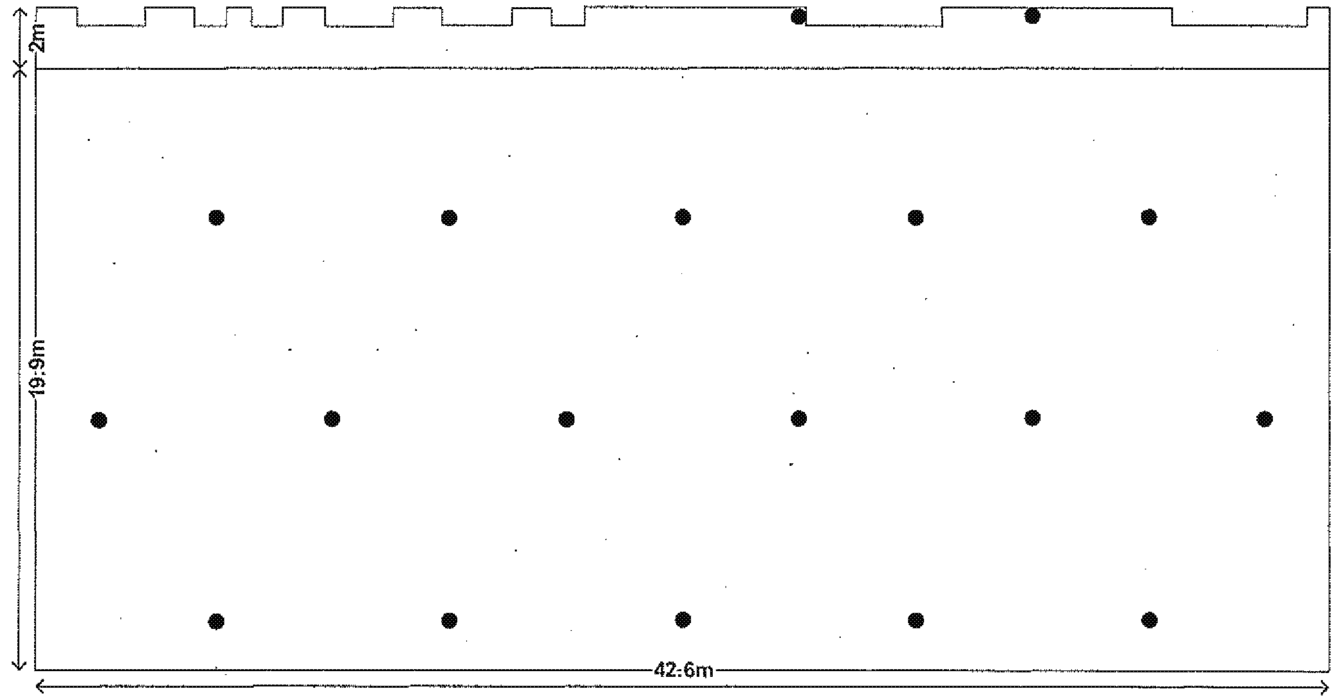
**Areas are estimates, may not sum to total due to rounding*

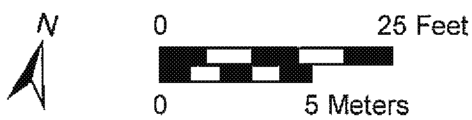


Note: Survey Unit and Floor Plan data are based on available documentation, and may not reflect current site conditions. Updated site maps will be prepared as part of the building surveys.

Data source: Department of the Navy Base Realignment and Closure report. "Final Final Status Survey Results, December 30, 2009, DCN: ECSD-5713-0072-0043" prepared by TetraTech. CTO No. 0072. Multiple drawings were georeferenced and digitized in GIS. Survey Unit data are based on figures 1-2 (2007) and 4-2 (2008). Trench Units from CH2M Phase 1 report. Dimensions are approximate.

Figure 4-10
Example Building Class 1 Survey Unit and Sample Locations (Building 366 Survey Unit 1)
Parcel G Work Plan
Former Hunters Point Naval Shipyard
San Francisco, California



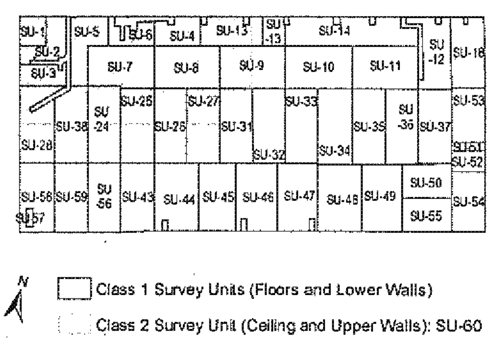


Legend

- Systematic Static and Swipe Location
- Estimated Ceiling Area* = 850 m²
- Estimated Upper Wall Area* = 74 m²

Total Estimated Area* = 923 m²

**Areas are estimates, may not sum to total due to rounding.*



Note: Survey Unit and Floor Plan data are based on available documentation, and may not reflect current site conditions. Updated site maps will be prepared as part of the building surveys.

Data source: Department of the Navy Base Realignment and Closure report, "Final Final Status Survey Results, December 30, 2009, DCN: ECSD-5713-0072-0043" prepared by TetraTech, CTO No. 0072. Multiple drawings were georeferenced and digitized in GIS. Survey Unit data are based on figures 1-2 (2007), 2-7 (2008), and 4-2 (2008). Trench Units from CH2M Phase 1 report. Dimensions are approximate.

Figure 4-11
Example Building Class 2 Survey Unit and Sample Locations (Building 366 Survey Unit 60)
Parcel G Work Plan
Former Hunters Point Naval Shipyard
San Francisco, California